JANUARY 1957 VOL. 2 NO. 1

A HEYWOOD TECHNICAL PUBLICATION

BRITISH CHEMICAL ENGINEERING

THE JOURNAL DEVOTED TO THE TECHNIQUES OF CHEMICAL ENGINEERING APPLIED TO INDUSTRY

CONTENTS

Page

1 **Digest**

7 **Leader**

8 **Fluidised Production of Phthalic Anhydride**

12 **Atomic Energy Presents the Chemical Engineer with New Problems**
by K. L. Stretch, M.A., Ll.B., A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E.

16 **Absorption of Carbon Dioxide in Solutions of Diethanolamine**
by D. R. Morris, B.Sc., Ph.D., and S. R. Watkins, M.Sc., F.R.I.C., M.I.Chem.E.

21 **The Design of Bubble-cap Plate Columns**
by T. V. Molesworth, B.Sc. (Tech.), A.M.I.Chem.E.

27 **A British Dodecyl-benzene Plant**

28 **Plastics Can Solve Your Equipment Fabrication Problems**
by S. A. Gregory, B.Sc., M.I.Chem.E.

30 **Heat-transfer Experiments with Extended Surfaces**

32 **Air-cooled Heat Exchangers**
by D. Kaye, B.Sc. (Eng), Chem. Eng.

34 **The N.C.B.'s Chesterfield Coking and By-products Plant**

38 **Harwell's Latest Materials-testing Reactor**

39 **Nomogram No. 8**

40 **American Letter**

42 **Process Engineer's Notebook**

44 **Book Reviews**

46 **Plant Equipment News**

52 **World of Chemicals**

54 **The Month's News in Brief**

Editor:
WILLIAM E. DICK, B.Sc.

Technical Editor:
J. O. S. MACDONALD,
B.Sc., A.R.I.C., A.M.I.Chem.E.

Assistant Editors:
WILLIAM D. CLIFFORD
G. DILLEY

BRITISH CHEMICAL ENGINEERING is published monthly by HEYWOOD & CO. LTD., Drury House, Russell Street, Drury Lane, London, W.C.2 Tel.: TEMple 3422. BRITISH CHEMICAL ENGINEERING is available by annual subscription at a price of £1 10s. 0d. sterling for 12 issues post free ($6 U.S.A. and Canada) or alternatively, by standing order through newsagents at 2s. 6d. per copy net. BRANCH OFFICE: 12 St. Ann's Square, Manchester. Tel.: Deansgate 3277. Entire contents are copyright and must not be reproduced without written permission.

BCE 639 for further information

TONNAGE OXYGEN PLANTS

and gas separation plants

British Oxygen Linde offer the combined experience and technical resources of two great companies —The British Oxygen Company Limited and Linde-Gesellschaft— designers and manufacturers of oxygen, nitrogen, and gas separation plants for more than fifty years.

BRITISH OXYGEN LINDE LIMITED

Bridgewater House, St. James's, London, S.W.1

BRITISH CHEMICAL ENGINEERING

DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

A Corrosion Research Centre?

THE need for a "corrosion research centre" on a "truly national basis" was urged by W. H. J. Vernon in an address to members of the Institution of Civil Engineers, in London, recently. The cost of maintaining metal installations, plus the cost of equipment which corrosion made unserviceable every year in Britain, was probably about £600m., he said.

The indirect costs of breakdowns in industry from such failures as a perforation in a tube in a power station's condenser caused by corrosion were incalculable. Specialists in the prevention of corrosion, the lecturer suggested, should become as normal a part of the industrial structure in Britain as they were in America. An increasing expenditure on corrosion control was a healthy sign so long as it reduced the direct and indirect cost of corrosion. Cathodic protection he described as "one of the most promising fields for development". Not only could it prevent corrosion, when installed from the start, but with bitumen-coated steel water-pipes where leaks had developed, it was found to suppress the leaks.

The Future of "Biochemical Engineering"

THE view that the "protean powers" of micro-organisms assured a growing importance in the future for "biochemical engineering" was expressed by Brigadier-General Sir Harold Hartley, F.R.S., in a special lecture to the School of Pharmacy, London University recently. The potentialities of this "new" branch of chemical engineering were shown in the "striking" fact that the mass of microbial protoplasm on this planet was five times as great as that of animal protoplasm, and in the observation that the amount of nitrogen fixed by micro-organisms in the soil was vastly greater than all that provided by nitrogenous fertilisers. As 75 per cent. of the body weight of algæ like chlorella at one stage consists of proteins, he said, those organisms had been suggested as an alternative source of food supply. By increasing the partial pressure of carbon dioxide in the solution in which the algæ are growing, the normally low photo-synthetic productivity of a ground area can be increased thirty-fold. The economics of the process are unpromising at present, but, he continued, these are early days and the world may need proteins very badly. Biochemical engineering was a "combined operation for the biochemist, the microbiologist, the geneticist and the chemical engineer". With its help we turn today to utilise the "almost incredible power" of micro-organisms for effecting chemical changes and for synthesising complex compounds.

Chemical Engineering Education

LAST month we did just mention the symposium on chemical engineering education which is to be held at Birmingham University on April 9-11. The full programme is now ready, and readers who require a copy should contact: The Symposium Manager, Chemical Engineering Department, The University, Edgbaston, Birmingham 15.

There will be four sessions dealing with the following themes—the requirements of industry; methods of training; new trends in teaching chemical engineering; and recruitment to the profession. Speakers from the universities will include Professors F. H. Garner, M. B. Donald, E. S. Sellers and J. M. Coulson. Dr. F. R. Venables of Birmingham College of Technology is to speak about technical college courses in chemical engineering, and the chairman of the Institution of Chemical Engineers examination board, Mr. G. U. Hopton, will discuss training by private study. The requirements of industry will be considered by the following speakers—Dr. D. Clayton, head of engineering research, Billingham Division of I.C.I.; Dr. F. Mayo, manager of the Fawley refinery; Mr. A. S. White, head of Harwell's chemical engineering division; Mr. J. P. V. Woollam and Mr. J. D. McFarlane of Simon Carves.

The scale of this important symposium reflects the tremendous emphasis that is being placed at the present time upon technological education. This stems from the real, if belated, understanding which now exists in the highest circles that our very survival as a nation depends upon increasing the output of highly trained scientists and engineers, amongst whom chemical engineers are second to none in importance.

This symposium will be of immense value to the furthering of the cause of chemical engineering, and we give it our warmest support. Above all, we hope that it will stimulate the teachers in universities technical colleges and schools to discuss their problems with each other and to air the many problems that are involved. It is important that this conference should regard it as axiomatic that it is mainly the ordinary teachers and lecturers who give our embryo chemical engineers their basic ideas about chemical engineering. The "meat" of chemical engineering courses is provided by these men, and the future of the profession depends as much upon their efforts as upon the professors, heads of departments and "managerial" technologists.

Enlargements at Manchester

IN a 140 pp. statement just published, the Principal of the Manchester College of Science and Technology, B. V. Bowden, sets out proposals for the enlargement of the College that is to place under the Government's plan for technological education. Although the College was, it is claimed, the first in the world to organise a course on chemical engineering, the present department for this subject is of a hopelessly inadequate size. In 1955, Dr. Bowden points out, 200 students who applied to enrol for that subject, only 25 could be accepted. To expand the department as fast as he and his colleagues think advisable they propose to make use of a large cotton mill which stands in the middle of the new campus. Because it is fifty years old they do not think that its useful life will be much more than ten to fifteen years. In October, 1957,

they expect to be able to accommodate a hundred undergraduates, and they hope to establish also a postgraduate diploma course that should attract another twenty or thirty students. The demand for chemical engineers is so great that plans are being made to expand associateship courses as well as university degree courses at the College. Dr. Bowden believes that if the university students are thrown together with the part-time students, the experience will be "most valuable" to both; each group can contribute something that the other lacks.

The creation of a separate department of nuclear energy with its own professor "cannot be delayed for more than a few years". At first, however, the chemical engineering department will be responsible for the work. The proposals also provide for a special section of the department being devoted to petroleum technology. Fuel technology and, eventually, "biochemical engineering" will also be taught in the department.

U.S. Trains More Chemical Engineers

THE spectacular rise of chemical engineering in the U.S.A.; novel trends in education for the profession, and the present structure of chemical engineering practice in the United States: these subjects are discussed in a stimulating report just published by the DSIR under the authorship of Dr. P. H. Calderbank (head of the Engineering Department of the Chemical Research Laboratory, Teddington). The facts are presented with infective enthusiasm.

The present output of chemical engineers in the United States, he says, is about 2,000 a year—one-tenth of the total number of engineers graduating in the country. (This figure is lower than some U.S. authorities have given.) Most chemical engineering schools have substantial expansion programmes well under way and a twofold increase in the number of students is shortly expected. Yet industries fear that the present acute shortage of chemical engineers will continue if the current rate of industrial expansion is maintained. The future trend in education, the author suggests, is indicated in the following prediction by Dean J. C. Elgin of Princetown University: "During the next 15 years the curriculum will begin to focus entirely on the principles and generalizations of the chemical engineering science. No effort in the university will be made to provide training in chemical engineering art. This responsibility will be assumed by industry. The unit operation organisation of the curriculum will disappear, to be replaced by such subjects as chemical engineering dynamics and kinetics; heat and mass transfer and fluid dynamics; nuclear processes; automatic control; and machine computations. Our ability to generalize will increase and the present sharp differentiations between the fields of engineering and even the branches of engineering science will disappear. The objective will be to educate an engineer-scientist in breadth and depth".

Industrial Co-operation

Although the titles, "University", "College" and "Technical Institute" have been variously bestowed on institutions for engineering education in the U.S.A., there is no obvious distinction to be made between these institutions so far as chemical engineering instruction is concerned.

Under "practice school", a method of instruction which has been made famous by the Massachusetts Institute of Technology, groups of students work in an industrial plant with their instructor on problems of interest to the host company. Industrial companies are usually willing to co-operate in this arrangement, which is generally considered to be a useful introduction to industrial life for the student. The "co-operative scheme" is essentially the same as Britain's "sandwich course". Only a few schools in highly industrialized areas in the north-east of the U.S.A. have such co-operative arrangements with industry. The "plant-design class" method, which is also well known in Britain, has been widely adopted in the U.S.A., students being required to co-operate with each other and their instructor in designing a full-scale plant.

Graduates who form the potential working force in chemical engineering are sometimes given good opportunities for further education since a number of companies co-operate with nearby universities to provide courses of lectures leading to the Master's, or even Ph.D. Research work done for the company, if publishable, is sometimes considered for the higher degree. Most chemical engineers whose interests are in research and development or in plant design take a Master's or Doctorate degree.

Dr. Calderbank pays a tribute to the "high standard of much of the post-graduate research work in the U.S.A.". Attention is now being directed to the unsteady state and transients, and this leads naturally to the principles governing automatic process control. Much of the work is sponsored by industry and the Armed Forces and by various foundations.

American Practice

As to chemical engineering practice, in larger companies specialisation has led to sub-divisions of the main functions of the engineer into such categories as the following:

(A) Provision and correlation of physico-chemical, thermodynamic and rate data; (B) development of plant design procedures; (C) process and equipment development; (D) economic evaluation; (E) plant operation and process improvement; and (F) detailed plant design.

Responsibility in American industry is widely disseminated. Incentives provide the impetus which ensures that this responsibility is effectively discharged and the rapid rate of expansion of industry ensures that the incentives are real. There is apparently no lack of excellent managerial staff, the author says, in a society which consciously does nothing to promote such a species. It is probably true that American equipment manufacturers offer customer service and advice on a scale not usual elsewhere.

The author does not consider the criticism that is sometimes made that Europe's chemical engineering literature is scattered is a valid one. In a postscript he points out that no criticism is intended of the excellent work done by British chemical engineering organisations, and draws attention to the great advantages in cheap raw materials and power supplies which the American industry enjoys.

Titanium and the Chemical Engineer

TITANIUM was one of the metals discussed in the special "Metals in Industry" supplement which *The Financial Times* published on December 10th. The two main titanium minerals are ilmenite and rutile. The latter is purer but less abundant. According to the author of *The Financial Times* article, Dr. J. W. Rodgers of I.C.I.'s Metals Division, the rutile used by industry is obtained from Australia, the United States, Brazil, Africa and Mexico. Important new deposits were recently discovered in Sierra Leone, which Dr. Rodgers did not mention. On the very day that his article appeared the newspapers carried the welcome news that a three-man mission headed by Sierra Leone's Minister of Mines had

come to London to discuss the mining of these rutile deposits.

The present high price of titanium militates against its use outside the aircraft industry. In a B.B.C. "Science Survey" talk, Mr. Michael Clapham, who is joint managing director of I.C.I.'s Metals Division, stressed that this is not likely to be a permanent feature of this metal. He said there are good reasons for thinking that in the next three years or so the cost of titanium will fall, perhaps to half the present figure. One thing that makes it expensive is that process scrap cannot be recovered just by putting it back in the melting pot. Mr. Clapham said that, as a result of research now in progress, it seems likely that quite soon titanium scrap will be re-used on a much greater scale than at present. When and if the price of titanium can be reduced, plenty of applications should materialise in the chemical industry.

Its resistance to corrosion is remarkable. In a wide range of acids and alkalis, titanium has a life many times that of the best constructional material now available. Commented Mr. Clapham: "Indeed, the main difficulty in talking about this property of titanium is that it hasn't yet been in use long enough for its life in most of the possible applications to be known".

A Basis for New Processes

He referred to one particular plant that had to be closed down every three or four months to replace the valve plates in a gas compressor line, which were made of alloy steel. These have been replaced by titanium, which appears to be as good as new at the end of three months. It cost perhaps £100 to put in the titanium: but the cost of closing the plant is measured in thousands of pounds each time. That case well illustrates the advantages of titanium. Other applications are being found in tanks and vessels for acid production, in pipes for acid fumes, in fans and in various types of heat exchanger. We agree entirely with Mr. Clapham's final remark that the list will grow as chemical engineers realise that a new structural material makes new processes possible. It is significant that one of the most interesting uses now being developed is in an advanced type of atomic energy installation, where the material being handled is radioactive so that the plant must be capable of being run for years without maintenance.

Spreading Nuclear Information

Information about advances in nuclear engineering was disseminated last month by at least three notable events—a symposium on the Calder Hall Works nuclear power plant, attended by more than 2,000 members (see also p. 30); the publication of the proceedings of the conference arranged by the Institute of Physics and held in July, 1956 on the physics of nuclear reactors; and the calling of a private conference by the U.K. Atomic Energy Authority for representatives of British plant manufacturers.

At the first-mentioned conference, the descriptions of the Calder Hall Works, presented by experts who had taken an important part in the design and construction of the plant, revealed a wealth of detail that previously had not been disclosed. Sir Claude Gibb, speaking in the discussion, went so far as to describe the conference as contributing more to engineering knowledge and to human well-being than any other that had ever been held. So much detail was released that it was obvious that the Authority's staff is confident that Britain can maintain the lead that she now has in nuclear power plant design.

Sir Christopher Hinton (Managing Director, Industrial Group U.K.A.E.A.), pointed out that, in planning the Calder Hall reactors, the designers had adhered—as James Watt had done when designing his early steam engines—to the sound engineering practice of making use of available scientific knowledge, materials and techniques to produce plants which were sufficiently economical and reliable. The Calder Hall piles were heavy, cumbersome and expensive in capital cost per kW, but they were inherently safe. The merits of the Calder Hall kind of reactor convinced Sir Christopher that similar plants would still be built twenty-five years hence. In the second half of the twenty-five year period, however the gas-cooled reactor would be replaced for some purposes by reactors using liquid coolants, and, in the very long term, would be superseded by the liquid-cooled kind. Sir Christopher recommended a two-pronged plan of action—to put all necessary effort into the development of the graphite-moderated gas-cooled reactors and, simultaneously, to press forward with the elaboration of other systems which are not now industrially attractive. By making improvements in the Calder Hall reactor, Britain could retain her present lead in nuclear power for at least ten years. Leadership would be maintained only by the development of reactors capable of substantially higher ratings, and it was in that direction in which the Authority was directing its attention.

The fourteen papers presented at the conference were divided under the headings, General Design, Technical Research Problems and Engineering Design.

A Private Conference

The proceedings of the conference on the Physics of Nuclear Reactors, which are now published as a 112 pp. supplement to the *British Journal of Applied Physics* is, in the words of Sir John Cockcroft, President of the Institute, "a useful record of the present stage of knowledge and of the gaps which need to be filled". Together with the proceedings of the Calder Hall symposium which are to be published later this year, they will form an invaluable compendium of the physics and the mechanical and chemical engineering on which the current nuclear engineering programme in Great Britain is based.

The private conference organised by the Atomic Energy Authority at Harwell, was attended by as many as 200 delegates representing about 100 industrial organisations. The conference, the first of its kind to be held by the Authority, was called to inform invited representatives of British plant manufacturers and electricity undertakings of the work that is being conducted by the Authority's staff on advanced types of nuclear reactors, and to discuss with them the ideas that will be followed in the future. The papers read were by leaders of research and development teams and are not to be published in detail.

During the course of the conference Mr. R. Hurst gave an account of the problems involved in the design of 100 MW homogenous aqueous reactor. Some of the greatest difficulties, he said, are associated with the continuous fuel processing techniques which might be used and with the handling of the blanket "slurries". Similar problems were described by Mr. J. Smith in a paper on the liquid-metal fuelled reactor in which bismuth may be used as the solvent metal An important problem was the development of an impermeable graphite moderator. It was possible that a beryllium moderator might have to be used, he said.

More development work has been done in the fast reactor field than for the other candidates for the third-stage reactor, and the present advanced state of this programme was described by Mr. H. Cartwright. He emphasised that

although the Dounreay experiment will "go critical" in the first half of 1958, this marks only the beginning of an extensive experimental programme aimed at obtaining the nuclear, metallurgical and engineering data required to design a prototype fast-power reactor. Whereas the engineering problems of design are considerable, it is in the metallurgical field that most work needs to be done to derive full advantage from such a reactor.

One of the most promising reactor systems, the organic liquid moderated reactor, for possible propulsion of ships, is being investigated by Harwell workers in collaboration with the British Shipbuilding Research Association, and is also being considered as a possible low-power output reactor of between 10 and 30 MW for the export market. Mr. H. W. Bowker, presenting a paper on the system, pointed out that a principal advantage of the system was its low pressure and higher operating temperature compared with those of the pressurised water reactor. The corrosion problems involved should be less severe than in other liquid systems and the rate of deterioration of possible organic coolants under irradiation is not sufficiently fast to make the system uneconomic.

Tapping Solar Energy

THAT a solar furnace of novel design is currently being developed commercially in the United States (by Arthur D. Little Inc., Cambridge Mass.) is an indication of the present stage of growth of this kind of high temperature technology. Work on the prototype is well forward and the furnace, which is being designed to reach temperatures of about 3,500°F, will be a model for others to be offered to research laboratories. A special use for the furnace will be in the study of the behaviour of materials at high temperatures and, as direct sunlight is needed only for short periods for this purpose, it is expected that the furnace will perform satisfactorily in any part of the U.S.A. It may not be unduly cynical to assume that research workers in parts of the world less favoured climatically will be denied the full value of these new tools.

Russia is planning to make use of the abundant sunshine in the Ararat plain in Armenia by building an experimental solar electric power station which will operate at 1200 kW. The movement of the mirrors in it will be controlled automatically with photo cells, and the solar energy will be caused to generate low-pressure steam. The electric power is to be used for land drainage and space heating.

Sucrochemistry—A New Industry?

THE possible development of a branch of the chemical industry, called in America sucrochemistry, which is based on the exploitation of the chemistry of sugar and of the byproducts of the sugar industry was discussed by Prof. L. F. Wiggins (director of Sugar Research, Imperial College of Tropical Agriculture, Trinidad) in a lecture to the Royal Society of Arts in London recently.

Sugar at a negotiated price of 4½d. lb. c.i.f. London Docks is not really out of phase economically with other general chemicals, he said. The sugar in molasses may be valued at about ¾d. per lb. The essential features of the sugar molecule are that it has eight hydroxyl groups and that it is composed of two different hexose units joined by a glycosidic linkage. The hydroxyl groups are readily esterfied with fatty acid residues. Sucrose octa-acetate for example is well known and is on the market in the United States as a denaturant for alcohol. Long chain fatty acids—such as palmitic acid can also be linked to sucrose, but the product is usually a mixture of compounds in which those containing five or six palmitate residues predominate, and it has no strikingly useful properties. Recently, it has been found possible to introduce a single fatty acid group into the sucrose molecule. Sucrose monostearate is made by alcoholysis using sucrose, methyl stearate, an alkaline catalyst, and a solvent which will dissolve both the sugar and the fatty acid ester. Assuming good solvent recovery, it has been calculated that sucrose monostearate could be made for about 21 cents (U.S.) per pound. This substance possesses the inherent characteristics of a surface-active agent, having water-repellent and water-attractive parts.

Lauric acid, when combined with sucrose, gives a product which is a better detergent than sucrose monostearate. The sugar detergents are non-toxic and tasteless, and are non-irritant to the skin and membranes of the eyes. Unsaturated fatty acids form products that have excellent drying oil properties.

A reaction of sucrose that is as yet not well understood is its reaction with hydrogen and ammonia in methanol. At about 130°C. and 100 atmospheres pressure ammonia and hydrogen disrupt the sugar molecule and convert it into 2—methylpiperazine. This reaction, in our hands, has only worked in poor yield, he said, but if this can be improved, it may be of some importance for 2—methylpiperazine could be used in making nylon-like synthetic textile fibres. It might replace the hexamethylene diamine used in ordinary nylon synthesis or be used in the pharmaceutical and veterinary fields.

New Appointments

ON April 1, 1957, Mr. George Brearley, F.R.I.C., M.I.Chem.E., will succeed Mr. J. Davidson Pratt as director of the Association of British Chemical Manufacturers. He was born in Batley in 1901, and took his degree at Leeds University. After spending several years engaged in the manufacture of dyestuffs, he joined Brotherton & Co. Ltd., for whom he worked for 28 years. As works manager at Bromborough, he was particularly identified with the development of the manufacture of hydrosulphites. He later became technical director at the firm's head office, and was finally appointed managing director, a position which he held for seven years until his resignation in 1953. He has also seen service on the boards of four other tar distillers and chemical manufacturers. Since he left Brotherton & Co., he has been a partner in Cremer and Brearley, the consultant chemical engineers. Mr. Brearley's A.B.C.M. activities have included membership of Group D and participation in Chemical Works Safety Conferences. He has also been active in A.C. & A.E. affairs and he was, in 1952, chairman of the Chemical Group. Within the S.C.I., he is chairman of the Annual Reports and Monographs Sub-Committee.

* * * *

P. V. Danckwerts, G.C., M.I.Chem.E., has left the Atomic Energy Authority to become Professor of Chemical Engineering Science at Imperial College of Science and Technology, London. He is 40 years old.

He graduated in 1939, after studying chemistry at Oxford under Mr. R. P. Bell. He then spent a year as a research chemist with the Fuller's Earth Union before joining the Navy. He served in the Navy for six years, first as a bomb disposal officer in various parts of the world, and then, after being wounded during the invasion of Sicily, at Combined Operations Headquarters. At the end of the war he went as a Commonwealth Fund Fellow to study chemical engineering at M.I.T., where he gained his Master's degree in Chemical Engineering Practice in 1948. On his return to Britain he joined the staff of the newly-formed Department of Chemical Engineering at Cambridge, and there he spent six years as a demonstrator and lecturer, helping to establish the curriculum and set the standards for the Chemical Engineering Tripos course.

DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

A Corrosion Research Centre?

THE need for a "corrosion research centre" on a "truly national basis" was urged by W. H. J. Vernon in an address to members of the Institution of Civil Engineers, in London, recently. The cost of maintaining metal installations, plus the cost of equipment which corrosion made unserviceable every year in Britain, was probably about £600m., he said.

The indirect costs of breakdowns in industry from such failures as a perforation in a tube in a power station's condenser caused by corrosion were incalculable. Specialists in the prevention of corrosion, the lecturer suggested, should become as normal a part of the industrial structure in Britain as they were in America. An increasing expenditure on corrosion control was a healthy sign so long as it reduced the direct and indirect cost of corrosion. Cathodic protection he described as "one of the most promising fields for development". Not only could it prevent corrosion, when installed from the start, but with bitumen-coated steel water-pipes where leaks had developed, it was found to suppress the leaks.

The Future of "Biochemical Engineering"

THE view that the "protean powers" of micro-organisms assured a growing importance in the future for "biochemical engineering" was expressed by Brigadier-General Sir Harold Hartley, F.R.S., in a special lecture to the School of Pharmacy, London University recently. The potentialities of this "new" branch of chemical engineering were shown in the "striking" fact that the mass of microbial protoplasm on this planet was five times as great as that of animal protoplasm, and in the observation that the amount of nitrogen fixed by micro-organisms in the soil was vastly greater than all that provided by nitrogenous fertilisers. As 75 per cent. of the body weight of algæ like chlorella at one stage consists of proteins, he said, those organisms had been suggested as an alternative source of food supply. By increasing the partial pressure of carbon dioxide in the solution in which the algæ are growing, the normally low photo-synthetic productivity of a ground area can be increased thirty-fold. The economics of the process are unpromising at present, but, he continued, these are early days and the world may need proteins very badly. Biochemical engineering was a "combined operation for the biochemist, the microbiologist, the geneticist and the chemical engineer". With its help we turn today to utilise the "almost incredible power" of micro-organisms for effecting chemical changes and for synthesising complex compounds.

Chemical Engineering Education

LAST month we did just mention the symposium on chemical engineering education which is to be held at Birmingham University on April 9-11. The full programme is now ready, and readers who require a copy should contact: The Symposium Manager, Chemical Engineering Department, The University, Edgbaston, Birmingham 15.

There will be four sessions dealing with the following themes—the requirements of industry; methods of training; new trends in teaching chemical engineering; and recruitment to the profession. Speakers from the universities will include Professors F. H. Garner, M. B. Donald, E. S. Sellers and J. M. Coulson. Dr. F. R. Venables of Birmingham College of Technology is to speak about technical college courses in chemical engineering, and the chairman of the Institution of Chemical Engineers examination board, Mr. G. U. Hopton, will discuss training by private study. The requirements of industry will be considered by the following speakers—Dr. D. Clayton, head of engineering research, Billingham Division of I.C.I.; Dr. F. Mayo, manager of the Fawley refinery; Mr. A. S. White, head of Harwell's chemical engineering division; Mr. J. P. V. Woollam and Mr. J. D. McFarlane of Simon Carves.

The scale of this important symposium reflects the tremendous emphasis that is being placed at the present time upon technological education. This stems from the real, if belated, understanding which now exists in the highest circles that our very survival as a nation depends upon increasing the output of highly trained scientists and engineers, amongst whom chemical engineers are second to none in importance.

This symposium will be of immense value to the furthering of the cause of chemical engineering, and we give it our warmest support. Above all, we hope that it will stimulate the teachers in universities technical colleges and schools to discuss their problems with each other and to air the many problems that are involved. It is important that this conference should regard it as axiomatic that it is mainly the ordinary teachers and lecturers who give our embryo chemical engineers their basic ideas about chemical engineering. The "meat" of chemical engineering courses is provided by these men, and the future of the profession depends as much upon their efforts as upon the professors, heads of departments and "managerial" technologists.

Enlargements at Manchester

IN a 140 pp. statement just published, the Principal of the Manchester College of Science and Technology, B. V. Bowden, sets out proposals for the enlargement of the College that is to place under the Government's plan for technological education. Although the College was, it is claimed, the first in the world to organise a course on chemical engineering, the present department for this subject is of a hopelessly inadequate size. In 1955, Dr. Bowden points out, 200 students who applied to enrol for that subject, only 25 could be accepted. To expand the department as fast as he and his colleagues think advisable they propose to make use of a large cotton mill which stands in the middle of the new campus. Because it is fifty years old they do not think that its useful life will be much more than ten to fifteen years. In October, 1957,

they expect to be able to accommodate a hundred undergraduates, and they hope to establish also a postgraduate diploma course that should attract another twenty or thirty students. The demand for chemical engineers is so great that plans are being made to expand associateship courses as well as university degree courses at the Colloge. Dr. Bowden believes that if the university students are thrown together with the part-time students, the experience will be "most valuable" to both; each group can contribute something that the other lacks.

The creation of a separate department of nuclear energy with its own professor "cannot be delayed for more than a few years". At first, however, the chemical engineering department will be responsible for the work. The proposals also provide for a special section of the department being devoted to petroleum technology. Fuel technology and, eventually, "biochemical engineering" will also be taught in the department.

U.S. Trains More Chemical Engineers

THE spectacular rise of chemical engineering in the U.S.A.; novel trends in education for the profession, and the present structure of chemical engineering practice in the United States: these subjects are discussed in a stimulating report just published by the DSIR under the authorship of Dr. P. H. Calderbank (head of the Engineering Department of the Chemical Research Laboratory, Teddington). The facts are presented with infective enthusiasm.

The present output of chemical engineers in the United States, he says, is about 2,000 a year—one-tenth of the total number of engineers graduating in the country. (This figure is lower than some U.S. authorities have given.) Most chemical engineering schools have substantial expansion programmes well under way and a twofold increase in the number of students is shortly expected. Yet industries fear that the present acute shortage of chemical engineers will continue if the current rate of industrial expansion is maintained. The future trend in education, the author suggests, is indicated in the following prediction by Dean J. C. Elgin of Princetown University: "During the next 15 years the curriculum will begin to focus entirely on the principles and generalizations of the chemical engineering science. No effort in the university will be made to provide training in chemical engineering art. This responsibility will be assumed by industry. The unit operation organisation of the curriculum will disappear, to be replaced by such subjects as chemical engineering dynamics and kinetics; heat and mass transfer and fluid dynamics; nuclear processes; automatic control; and machine computations. Our ability to generalize will increase and the present sharp differentiations between the fields of engineering and even the branches of engineering science will disappear. The objective will be to educate an engineer-scientist in breadth and depth".

Industrial Co-operation

Although the titles, "University", "College" and "Technical Institute" have been variously bestowed on institutions for engineering education in the U.S.A., there is no obvious distinction to be made between these institutions so far as chemical engineering instruction is concerned.

Under "practice school", a method of instruction which has been made famous by the Massachusetts Institute of Technology, groups of students work in an industrial plant with their instructor on problems of interest to the host company. Industrial companies are usually willing to co-operate in this arrangement, which is generally considered to be a useful introduction to industrial life for the student. The "co-operative scheme" is essentially the same as Britain's "sandwich course". Only a few schools in highly industrialized areas in the north-east of the U.S.A. have such co-operative arrangements with industry. The "plant-design class" method, which is also well known in Britain, has been widely adopted in the U.S.A., students being required to co-operate with each other and their instructor in designing a full-scale plant.

Graduates who form the potential working force in chemical engineering are sometimes given good opportunities for further education since a number of companies co-operate with nearby universities to provide courses of lectures leading to the Master's, or even Ph.D. Research work done for the company, if publishable, is sometimes considered for the higher degree. Most chemical engineers whose interests are in research and development or in plant design take a Master's or Doctorate degree.

Dr. Calderbank pays a tribute to the "high standard of much of the post-graduate research work in the U.S.A.". Attention is now being directed to the unsteady state and transients, and this leads naturally to the principles governing automatic process control. Much of the work is sponsored by industry and the Armed Forces and by various foundations.

American Practice

As to chemical engineering practice, in larger companies specialisation has led to sub-divisions of the main functions of the engineer into such categories as the following:

(A) Provision and correlation of physico-chemical, thermodynamic and rate data; (B) development of plant design procedures; (C) process and equipment development; (D) economic evaluation; (E) plant operation and process improvement; and (F) detailed plant design.

Responsibility in American industry is widely disseminated. Incentives provide the impetus which ensures that this responsibility is effectively discharged and the rapid rate of expansion of industry ensures that the incentives are real. There is apparently no lack of excellent managerial staff, the author says, in a society which consciously does nothing to promote such a species. It is probably true that American equipment manufacturers offer customer service and advice on a scale not usual elsewhere.

The author does not consider the criticism that is sometimes made that Europe's chemical engineering literature is scattered is a valid one. In a postscript he points out that no criticism is intended of the excellent work done by British chemical engineering organisations, and draws attention to the great advantages in cheap raw materials and power supplies which the American industry enjoys.

Titanium and the Chemical Engineer

TITANIUM was one of the metals discussed in the special "Metals in Industry" supplement which *The Financial Times* published on December 10th. The two main titanium minerals are ilmenite and rutile. The latter is purer but less abundant. According to the author of *The Financial Times* article, Dr. J. W. Rodgers of I.C.I.'s Metals Division, the rutile used by industry is obtained from Australia, the United States, Brazil, Africa and Mexico. Important new deposits were recently discovered in Sierra Leone, which Dr. Rodgers did not mention. On the very day that his article appeared the newspapers carried the welcome news that a three-man mission headed by Sierra Leone's Minister of Mines had

come to London to discuss the mining of these rutile deposits.

The present high price of titanium militates against its use outside the aircraft industry. In a B.B.C. "Science Survey" talk, Mr. Michael Clapham, who is joint managing director of I.C.I.'s Metals Division, stressed that this is not likely to be a permanent feature of this metal. He said there are good reasons for thinking that in the next three years or so the cost of titanium will fall, perhaps to half the present figure. One thing that makes it expensive is that process scrap cannot be recovered just by putting it back in the melting pot. Mr. Clapham said that, as a result of research now in progress, it seems likely that quite soon titanium scrap will be re-used on a much greater scale than at present. When and if the price of titanium can be reduced, plenty of applications should materialise in the chemical industry.

Its resistance to corrosion is remarkable. In a wide range of acids and alkalis, titanium has a life many times that of the best constructional material now available. Commented Mr. Clapham: "Indeed, the main difficulty in talking about this property of titanium is that it hasn't yet been in use long enough for its life in most of the possible applications to be known".

A Basis for New Processes

He referred to one particular plant that had to be closed down every three or four months to replace the valve plates in a gas compressor line, which were made of alloy steel. These have been replaced by titanium, which appears to be as good as new at the end of three months. It cost perhaps £100 to put in the titanium: but the cost of closing the plant is measured in thousands of pounds each time. That case well illustrates the advantages of titanium. Other applications are being found in tanks and vessels for acid production, in pipes for acid fumes, in fans and in various types of heat exchanger. We agree entirely with Mr. Clapham's final remark that the list will grow as chemical engineers realise that a new structural material makes new processes possible. It is significant that one of the most interesting uses now being developed is in an advanced type of atomic energy installation, where the material being handled is radioactive so that the plant must be capable of being run for years without maintenance.

Spreading Nuclear Information

Information about advances in nuclear engineering was disseminated last month by at least three notable events—a symposium on the Calder Hall Works nuclear power plant, attended by more than 2,000 members (see also p. 30); the publication of the proceedings of the conference arranged by the Institute of Physics and held in July, 1956 on the physics of nuclear reactors; and the calling of a private conference by the U.K. Atomic Energy Authority for representatives of British plant manufacturers.

At the first-mentioned conference, the descriptions of the Calder Hall Works, presented by experts who had taken an important part in the design and construction of the plant, revealed a wealth of detail that previously had not been disclosed. Sir Claude Gibb, speaking in the discussion, went so far as to describe the conference as contributing more to engineering knowledge and to human well-being than any other that had ever been held. So much detail was released that it was obvious that the Authority's staff is confident that Britain can maintain the lead that she now has in nuclear power plant design.

Sir Christopher Hinton (Managing Director, Industrial Group U.K.A.E.A.), pointed out that, in planning the Calder Hall reactors, the designers had adhered—as James Watt had done when designing his early steam engines—to the sound engineering practice of making use of available scientific knowledge, materials and techniques to produce plants which were sufficiently economical and reliable. The Calder Hall piles were heavy, cumbersome and expensive in capital cost per kW, but they were inherently safe. The merits of the Calder Hall kind of reactor convinced Sir Christopher that similar plants would still be built twenty-five years hence. In the second half of the twenty-five year period, however the gas-cooled reactor would be replaced for some purposes by reactors using liquid coolants, and, in the very long term, would be superseded by the liquid-cooled kind. Sir Christopher recommended a two-pronged plan of action—to put all necessary effort into the development of the graphite-moderated gas-cooled reactors and, simultaneously, to press forward with the elaboration of other systems which are not now industrially attractive. By making improvements in the Calder Hall reactor, Britain could retain her present lead in nuclear power for at least ten years. Leadership would be maintained only by the development of reactors capable of substantially higher ratings, and it was in that direction in which the Authority was directing its attention.

The fourteen papers presented at the conference were divided under the headings, General Design, Technical Research Problems and Engineering Design.

A Private Conference

The proceedings of the conference on the Physics of Nuclear Reactors, which are now published as a 112 pp. supplement to the *British Journal of Applied Physics* is, in the words of Sir John Cockcroft, President of the Institute, "a useful record of the present stage of knowledge and of the gaps which need to be filled". Together with the proceedings of the Calder Hall symposium which are to be published later this year, they will form an invaluable compendium of the physics and the mechanical and chemical engineering on which the current nuclear engineering programme in Great Britain is based.

The private conference organised by the Atomic Energy Authority at Harwell, was attended by as many as 200 delegates representing about 100 industrial organisations. The conference, the first of its kind to be held by the Authority, was called to inform invited representatives of British plant manufacturers and electricity undertakings of the work that is being conducted by the Authority's staff on advanced types of nuclear reactors, and to discuss with them the ideas that will be followed in the future. The papers read were by leaders of research and development teams and are not to be published in detail.

During the course of the conference Mr. R. Hurst gave an account of the problems involved in the design of 100 MW homogenous aqueous reactor. Some of the greatest difficulties, he said, are associated with the continuous fuel processing techniques which might be used and with the handling of the blanket "slurries". Similar problems were described by Mr. J. Smith in a paper on the liquid-metal fuelled reactor in which bismuth may be used as the solvent metal An important problem was the development of an impermeable graphite moderator. It was possible that a beryllium moderator might have to be used, he said.

More development work has been done in the fast reactor field than for the other candidates for the third-stage reactor, and the present advanced state of this programme was described by Mr. H. Cartwright. He emphasised that

although the Dounreay experiment will "go critical" in the first half of 1958, this marks only the beginning of an extensive experimental programme aimed at obtaining the nuclear, metallurgical and engineering data required to design a prototype fast-power reactor. Whereas the engineering problems of design are considerable, it is in the metallurgical field that most work needs to be done to derive full advantage from such a reactor.

One of the most promising reactor systems, the organic liquid moderated reactor, for possible propulsion of ships, is being investigated by Harwell workers in collaboration with the British Shipbuilding Research Association, and is also being considered as a possible low-power output reactor of between 10 and 30 MW for the export market. Mr. H. W. Bowker, presenting a paper on the system, pointed out that a principal advantage of the system was its low pressure and higher operating temperature compared with those of the pressurised water reactor. The corrosion problems involved should be less severe than in other liquid systems and the rate of deterioration of possible organic coolants under irradiation is not sufficiently fast to make the system uneconomic.

Tapping Solar Energy

THAT a solar furnace of novel design is currently being developed commercially in the United States (by Arthur D. Little Inc., Cambridge Mass.) is an indication of the present stage of growth of this kind of high temperature technology. Work on the prototype is well forward and the furnace, which is being designed to reach temperatures of about 3,500°F, will be a model for others to be offered to research laboratories. A special use for the furnace will be in the study of the behaviour of materials at high temperatures and, as direct sunlight is needed only for short periods for this purpose, it is expected that the furnace will perform satisfactorily in any part of the U.S.A. It may not be unduly cynical to assume that research workers in parts of the world less favoured climatically will be denied the full value of these new tools.

Russia is planning to make use of the abundant sunshine in the Ararat plain in Armenia by building an experimental solar electric power station which will operate at 1200 kW. The movement of the mirrors in it will be controlled automatically with photo cells, and the solar energy will be caused to generate low-pressure steam. The electric power is to be used for land drainage and space heating.

Sucrochemistry—A New Industry?

THE possible development of a branch of the chemical industry, called in America sucrochemistry, which is based on the exploitation of the chemistry of sugar and of the byproducts of the sugar industry was discussed by Prof. L. F. Wiggins (director of Sugar Research, Imperial College of Tropical Agriculture, Trinidad) in a lecture to the Royal Society of Arts in London recently.

Sugar at a negotiated price of 4½d. lb. c.i.f. London Docks is not really out of phase economically with other general chemicals, he said. The sugar in molasses may be valued at about ½d. per lb. The essential features of the sugar molecule are that it has eight hydroxyl groups and that it is composed of two different hexose units joined by a glycosidic linkage. The hydroxyl groups are readily esterfied with fatty acid residues. Sucrose octa-acetate for example is well known and is on the market in the United States as a denaturant for alcohol. Long chain fatty acids—such as palmitic acid can also be linked to sucrose, but the product is usually a mixture of compounds in which those containing five or six palmitate residues predominate, and it has no strikingly useful properties. Recently, it has been found possible to introduce a single fatty acid group into the sucrose molecule. Sucrose monostearate is made by alcoholysis using sucrose, methyl stearate, an alkaline catalyst, and a solvent which will dissolve both the sugar and the fatty acid ester. Assuming good solvent recovery, it has been calculated that sucrose monostearate could be made for about 21 cents (U.S.) per pound. This substance possesses the inherent characteristics of a surface-active agent, having water-repellent and water-attractive parts.

Lauric acid, when combined with sucrose, gives a product which is a better detergent than sucrose monostearate. The sugar detergents are non-toxic and tasteless, and are non-irritant to the skin and membranes of the eyes. Unsaturated fatty acids form products that have excellent drying oil properties.

A reaction of sucrose that is as yet not well understood is its reaction with hydrogen and ammonia in methanol. At about 130°C. and 100 atmospheres pressure ammonia and hydrogen disrupt the sugar molecule and convert it into 2—methylpiperazine. This reaction, in our hands, has only worked in poor yield, he said, but if this can be improved, it may be of some importance for 2—methylpiperazine could be used in making nylon-like synthetic textile fibres. It might replace the hexamethylene diamine used in ordinary nylon synthesis or be used in the pharmaceutical and veterinary fields.

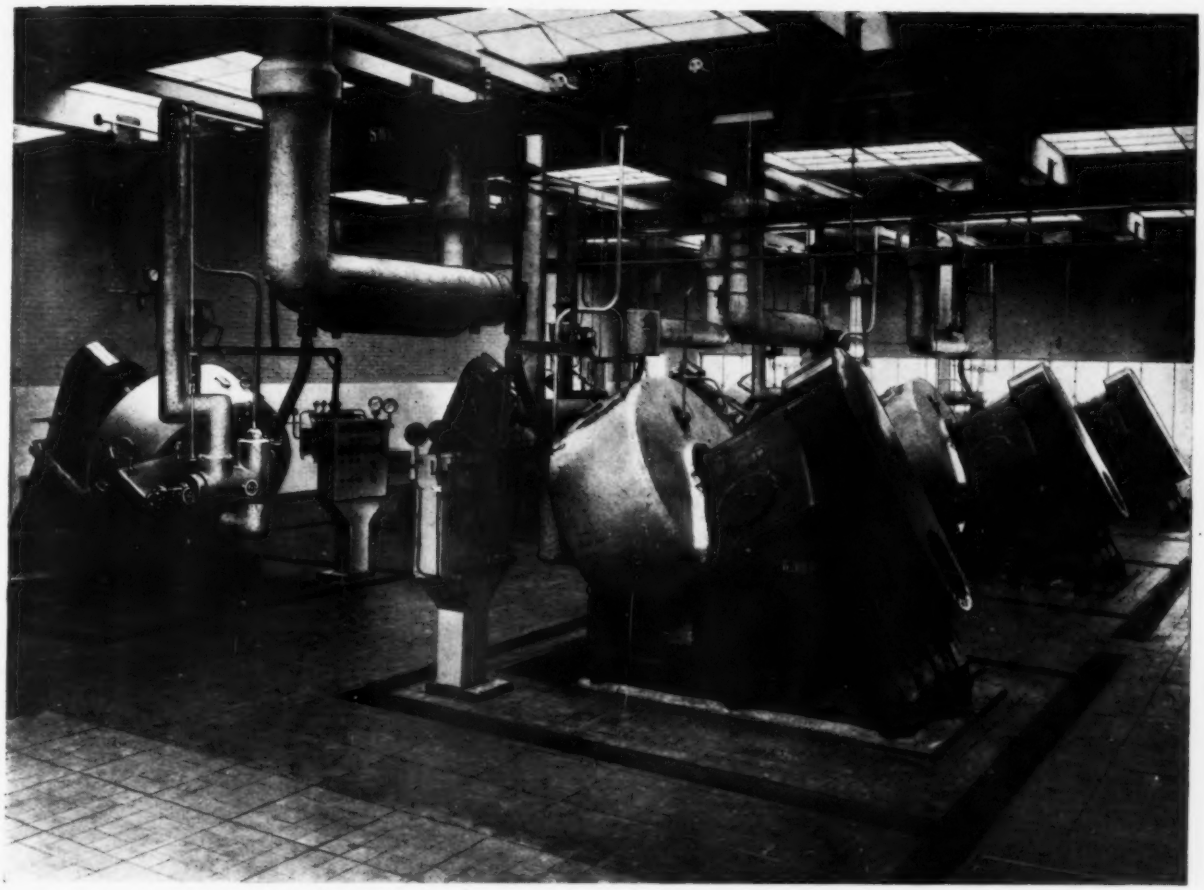
New Appointments

ON April 1, 1957, Mr. George Brearley, F.R.I.C., M.I.Chem.E., will succeed Mr. J. Davidson Pratt as director of the Association of British Chemical Manufacturers. He was born in Batley in 1901, and took his degree at Leeds University. After spending several years engaged in the manufacture of dyestuffs, he joined Brotherton & Co. Ltd., for whom he worked for 28 years. As works manager at Bromborough, he was particularly identified with the development of the manufacture of hydrosulphites. He later became technical director at the firm's head office, and was finally appointed managing director, a position which he held for seven years until his resignation in 1953. He has also seen service on the boards of four other tar distillers and chemical manufacturers. Since he left Brotherton & Co., he has been a partner in Cremer and Brearley, the consultant chemical engineers. Mr. Brearley's A.B.C.M. activities have included membership of Group D and participation in Chemical Works Safety Conferences. He has also been active in A.C. & A.E. affairs and he was, in 1952, chairman of the Chemical Group. Within the S.C.I., he is chairman of the Annual Reports and Monographs Sub-Committee.

* * * *

P. V. Danckwerts, G.C., M.I.Chem.E., has left the Atomic Energy Authority to become Professor of Chemical Engineering Science at Imperial College of Science and Technology, London. He is 40 years old.

He graduated in 1939, after studying chemistry at Oxford under Mr. R. P. Bell. He then spent a year as a research chemist with the Fuller's Earth Union before joining the Navy. He served in the Navy for six years, first as a bomb disposal officer in various parts of the world, and then, after being wounded during the invasion of Sicily, at Combined Operations Headquarters. At the end of the war he went as a Commonwealth Fund Fellow to study chemical engineering at M.I.T., where he gained his Master's degree in Chemical Engineering Practice in 1948. On his return to Britain he joined the staff of the newly-formed Department of Chemical Engineering at Cambridge, and there he spent six years as a demonstrator and lecturer, helping to establish the curriculum and set the standards for the Chemical Engineering Tripos course.



BROADBENT PLOUGHING CENTRIFUGALS INSTALLED AT THE WILTON WORKS OF IMPERIAL CHEMICAL INDUSTRIES

successful processing—

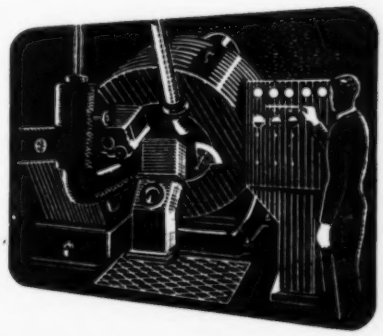
is not accidental—it results from patient and carefully planned research and calls for exceptionally skilled manufacturing techniques.

BROADBENT CENTRIFUGALS are called in to perform many difficult duties in modern chemical processing and it is significant that the problem of producing paraxylene, a basic constituent of "TERYLENE", is entrusted to them at the Wilton Works of Imperial Chemical Industries.

Conditions are far from easy, and the materials are handled at extremely low temperatures with explosion risks.

** the answer to your separating problems!*

BROADBENT CENTRIFUGALS



THOMAS BROADBENT & SONS LTD., HUDDERSFIELD

Telephone 5520 6 lines
Grams 'BROADBENT' HUDDS.

IF YOU ARE FACED WITH *ATTACK*

from corrosive liquors & gases . . .

IMPROVED GREY (*Sodium silicate type*). For Dilute Acid conditions.

DOUBLE WHITE (*Potassium silicate type*). For Concentrated Acids.

KIER. For Hot Concentrated Alkalis.

RUBEX (*Rubber Latex type*). For Dilute Acid/Alkali conditions.

ESSAR (W) (*Furane Resin type*). For Concentrated Acid/Alkali conditions.

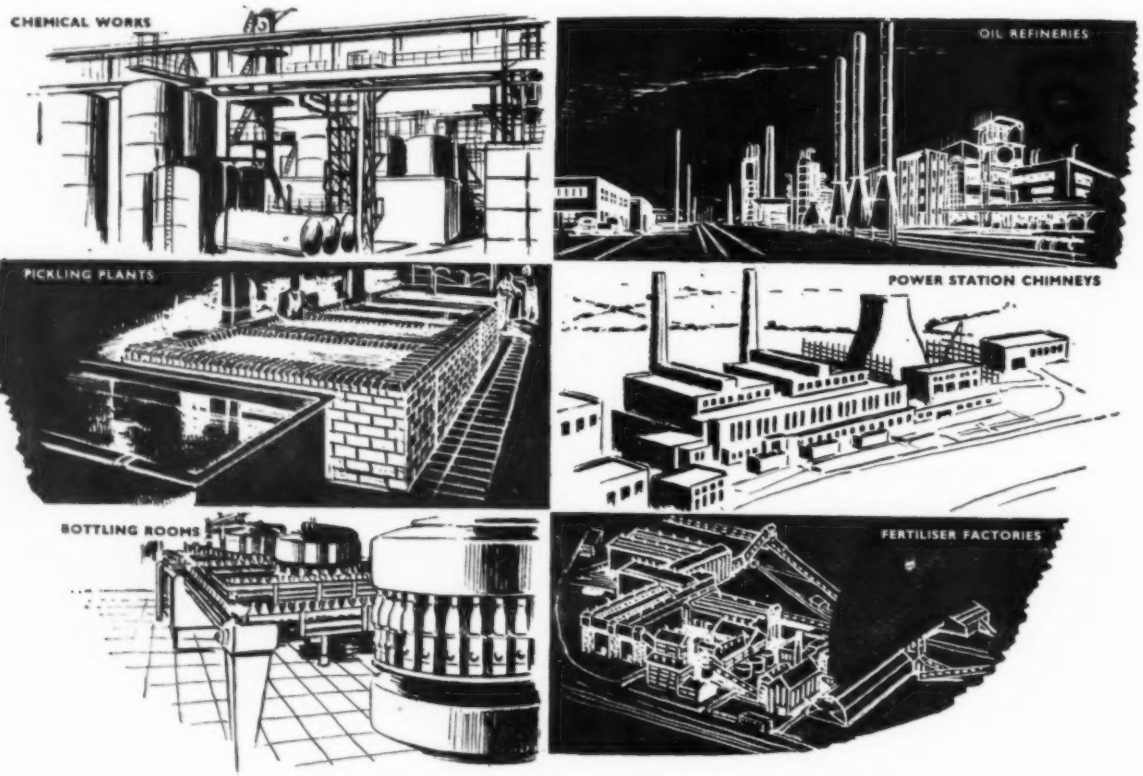
ESSAR (B) (*Furane Resin type*). For Hydrofluoric Acids.

ENOLAR (*Phenolic/Furane Resin type*). For Oxidising Acids and Alkalis.

ENNAR (*Cashew Resin type*). For Flexible Acid/Alkali conditions.

specify HAWORTH CEMENTS

as used regularly in—



HEAD OFFICE & WORKS:
Irwell Chemical Works,
RAMSBOTTOM,
MANCHESTER.
'Phones: Ramsbottom 2067, 3079.
'Grams: "Cements" Ramsbottom

F. HAWORTH (A.R.C.) LTD.
Ramsbottom LANCS

LONDON OFFICE:
40 Buckingham Palace Road,
LONDON, S.W.1
Phone: TATe Gallery 3861.
'Grams: "CHEMBRIK" Sowest, London

CORROSION SPECIALISTS FOR 50 YEARS

dm HW. 23

BRITISH CHEMICAL ENGINEERING
A HEYWOOD TECHNICAL PUBLICATION

The Growth of High-pressure Technology

IN the high-pressure field a great deal of pure scientific research has been carried out, and there have been considerable achievements in the realm of high-pressure technology. The relationship of the fundamental research to the technology has not, however, been as close as one might expect, and as a result many of the startlingly novel discoveries made by the scientists have not yet been considered from the point of view of their possible application in new industrial processes. Outstanding among the scientists who have investigated the behaviour of matter under high-pressure conditions is P. W. Bridgman, of Harvard, who has subjected all kinds of materials to pressures of up to 425,000 atmospheres. Only one of the major new techniques which he devised has so far been utilised within an industrial organisation, and that provides the basis of the process for making artificial diamonds which General Electric is operating at Schenectady.

Bridgman has discovered some remarkably interesting transformations—for example, the conversion of phosphorus into a black form that has metallic properties. What the chemical industry calls high-pressure technology is concerned mainly with a different class of transformation. The synthetic ammonia process in which nitrogen and hydrogen are made to combine under high pressure is one of the most striking and important examples of what this branch of technology has achieved. Others that spring immediately to mind are the oil-from-coal processes and the I.C.I. polythene process. The introduction of high-pressure chemical processes was a revolutionary advance, a fact which was recognised by the award of no less than three Nobel prizes for chemistry to the pioneers in this field—Fritz Haber, Carl Bosch and Friedrich Bergius. Germany led the world in the exploitation of high-pressure chemistry, but this branch of technology is now well established in every country with a sizeable chemical industry, and the world list of high-pressure plants is steadily increasing. Moreover, the number of different chemical processes carried out under elevated pressures has grown rapidly. The two standard text-books, by H. Tongue and D. M. Newitt respectively, have been rendered somewhat out-of-date by the rate of progress in this field, but a new volume has just appeared which goes a long way to filling the gap. This is *High-pressure Technology*, by Prof. E. W. Comings, (McGraw-Hill, 1956, 572 pp., 86s. 6d.).

To this sector of the chemical industry, science has contributed a great deal. But from the very outset high-pressure technologists have had to depend to a large extent on an empirical approach. The design of high-pressure equipment requires the application of concepts more complex than those required for operations at atmospheric pressure, and, as Professor Comings says, "Much of this design is based on sound scientific principles, but a considerable part depends on experience and is largely an art".

Many of the problems which arise in the course of developing high-pressure processes are unusually tricky. Sometimes quite novel phenomena are encountered, and then it may be necessary to investigate the basic phenomena involved before attempting to tackle the particular practical problem. The development of Haber's synthetic ammonia process, illustrates the point. After Haber had carried out a systematic study of the reaction over a large range of pressures, he wrote a report for Badische Anilin und Soda Fabrik suggesting that the best conditions for an industrial process would be about 500°C and 200 atmospheres pressure with a suitable catalyst.

The major development problem was how to produce a good reaction chamber. A tube of ordinary carbon steel did not stand up to the conditions. After repeated failures and many explosions, it was realised that the hydrogen under pressure was de-carburising the steel. This problem might have been tackled by searching for a better type of steel, but without intensive metallurgical research there was little hope of that approach proving successful. In fact, what happened was that this problem was circumvented. The idea that made this feasible was Carl Bosch's greatest contribution to the Haber process. Accepting the principle that they should construct the apparatus of available materials, he replaced Haber's single-walled vessel by two tubes, one inside the other. The outer tube (which was kept at a low temperature) was designed to stand high pressure and was made of ordinary steel. The material of the inner tube, which did not need to withstand pressure, was chosen for its resistance to attack by the hot gases; this material was a special alloy steel. In a short time Bosch had successfully organised the erection of an efficient plant with an annual capacity of 7,000 tons. When the war started, ammonia production at Leuna was pushed up rapidly and by 1918 more nitrogen was being "fixed" in that one installation than had previously been imported in the form of Chile saltpetre. After the war several countries rapidly adopted the Haber process. In Britain, Synthetic Ammonia & Nitrates went into production at Billingham on a large scale in the early 1920s.

The original Haber process has been continuously modified, and Prof. Comings reviews most of the major variations in his book. We were surprised to find that in the section of his book dealing with ammonia synthesis the author includes nothing about high-pressure processes as operated in Britain, though he cites technical data from Germany and Italy.

In World War II Germany relied very heavily on the output of its oil-from-coal plants. This high-pressure hydrogenation process was devised by Bergius, and put into large-scale production by I.G. Farben. The development stage was lengthy and it is said to have cost I.G. Farben £5 million. Several countries have exploited the process under licence, and I.G. Farben recouped all their development costs from one single licensee. Britain has produced quite large amounts of oil by this method.

As experience of high-pressure processing grows, it becomes easier to extrapolate and to develop new processes. The production of butadiene polymers, for example, has benefited from the experience gained in polythene manufacture. Inevitably, the growth rate of high-pressure technology is on the increase, just as the variety of chemical syntheses within this field is increasing.

FLUIDISED PRODUCTION OF PHTHALIC ANHYDRIDE

Several large fluidised-catalyst plants are now successfully producing phthalic anhydride. The product is purer and the yields appreciably higher than those obtained with fixed-bed plants

THE fame of the fluidised-catalyst method for producing phthalic anhydride stems from the intrinsic technical elegance of this chemical engineering achievement. It has aroused an interest among the experts which is out of all proportion to the quantity of phthalic anhydride produced by this method. At the end of the war only one fluidised-catalyst plant existed—the Sherwin-Williams plant in the U.S.A. Since 1945 several phthalic anhydride units have been erected in Britain, and all except one have been fluidised-catalyst plants. This is a sure indication that chemical engineers recognise that this method provides the most satisfactory solution of the production problems involved in the manufacture of phthalic anhydride.

The advantages of the fluidised-catalyst method have been summarised by Dr. H. L. Riley[1] in a recent lecture to the Chemical Engineering Group of the Society of Chemical Industry. The advantages which he attributed to it on that occasion are as follows:

(i) The operation of the reactor at a uniform and easily controlled temperature: this results in a much purer product with smaller losses in the subsequent vacuum distillation.

(ii) The use of much lower air-naphthalene ratios: in fixed-bed reactors it is necessary to work with excess air in order to avoid explosive air-naphthalene mixtures, but in the fluidised-catalyst method the catalyst dust effectively "stone dusts" the interior of the reactor and so eliminates the danger of explosion. Compression costs are reduced.

(iii) Greater safety of operation: not only is explosion risk in the reactor eliminated, but the lower concentration of oxygen in the product gas stream means less danger of fire and explosion in the condensation system.

(iv) Condensation simplified: the smaller volume of product gases per unit of product somewhat simplifies condensation problems.

(v) Utilisation of heat of reaction: the hot fluid catalyst can be used to generate high-pressure steam. (The amount of heat generated in the production of phthalic anhydride is indicated in the following equation:
Naphthalene ⟶ phthalic anhydride + 428 kg. calories).

Accurate Temperature Control

An outstanding advantage of the fluidised process is *the accurate control of temperature* that is possible. This is most important, since it means that "hot spots" inside the reactor can be avoided; local over-heating needs to be eliminated because a rise of 5-10°C can lead to a substantial production of maleic anhydride.

Phthalic anhydride has been in commercial production for many years, though the world's first fluidised-catalyst plant was not put into operation until 1944. Initially, this

Table 1. Details of various fluidised-bed phthalic anhydride plant designs. All plants have been built roughly on the same plan: the reactor height is of the same order in all cases, but the horizontal dimensions (diameter) differ according to the capacity.

	Standard Oil Patent (B.P. 568.913; 1941)	Sherwin-Williams Plant	United Coke & Chemicals Plant, Rotherham	I.C.I. Plant, Wilton
Throughput/Output	1000 lb/hr naphthalene	(*stated*) 400 lb/hr naphthalene (*probable*) 1600 lb/hr naphthalene	*c.* 1500 lb/hr naphthalene	(*design figure**) 16,000 tons/year (*probable output*) 1 ton/hr
Reactor Dimensions: Diameter ... ... Height	4 ft 2 in. 20 ft	5 ft 30 ft	Comparable to those of Sherwin-Williams Plant	*c.* 10 ft 6 in. *c.* 24 ft
Air/Naphthalene Ratio	30:1 (by volume)	15 lb air:1 lb naphthalene	About the same as in Sherwin-Williams Plant	About the same as in Sherwin-Williams Plant
Reactor Temperature	690°F	680-700°F	—	*c.* 750°F

* *Chemical Trade Journal*, 1952, **130**, 694; 1952, **130**, 998.

chemical was required as an intermediate in dyestuffs production, being used directly in the manufacture of such dyes as eosin, rhodamines, quinoline yellow and copper phthalo cyanine. It became even more valuable, as it opened up the production of all anthraquinone vat dyes at reasonable prices.[2] In 1927 production began of oil-modified alkyds for the paint industry, and this necessitated increased production of phthalic anhydride. The first application accounts for the possession of phthalic anhydride plants by I.C.I.'s Dyestuffs Division, for example, at Huddersfield, Grangemouth and Wilton. Its use in connection with paint manufacture explains why firms like Postan have become producers of phthalic anhydride. The demand for this chemical was further increased when phthalic esters (e.g., phthalates of dimethyl, diethyl, dibutyl, diamyl, dioctyl and diphenyl) were exploited as plasticisers.*

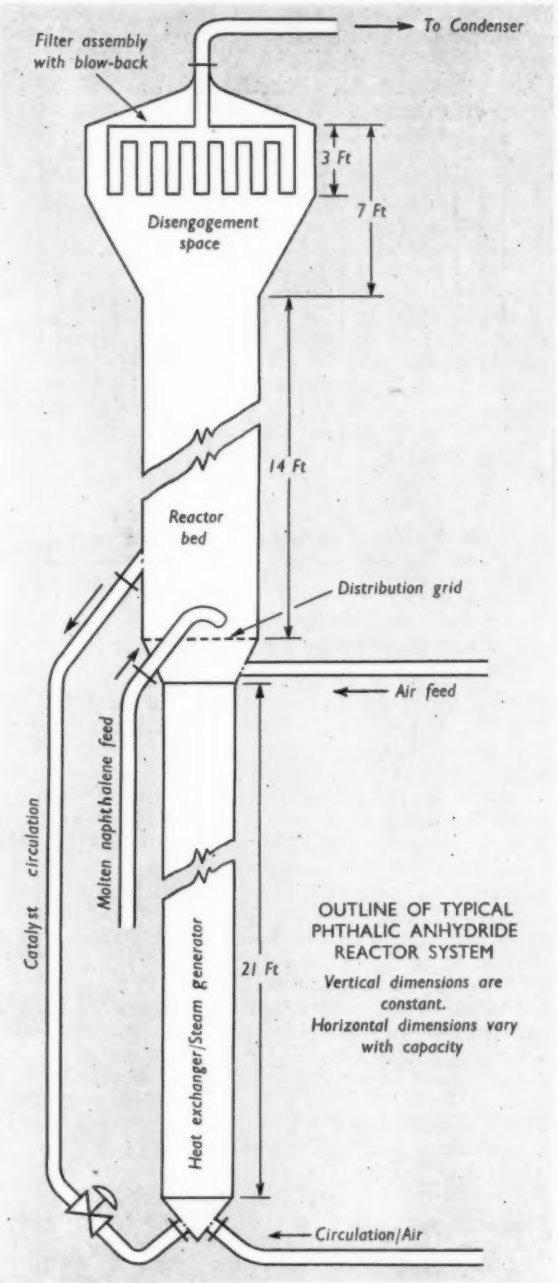
At the present time, approximately 350 million lb. of phthalic anhydride are being produced annually in the U.S.A. It has been estimated that inside two decades production will have to be stretched to 2 (U.S.) billion lb. per year.[3] A similar sixfold expansion of phthalic anhydride production may well materialise in the United Kingdom; our present output stands at between 20,000 and 25,000 tons a year.

The Two Manufacturing Processes

Only two processes have proved important for the industrial production of phthalic anhydride. The first to be developed was *the oxidation of naphthalene in the liquid phase* by concentrated sulphuric acid (catalysed by mercuric sulphate). Until the end of World War I, this process accounted for the entire production of phthalic anhydride.

The second process was *the modern vapour-phase oxidation of naphthalene with air* over a catalyst (vanadium pentoxide). The basis of this process was discovered almost simultaneously in Germany and the U.S.A. In 1916 Wohl filed his patent (G.P. 379,822), which covered the use of vanadium pentoxide as the catalyst at between 300 and 580°C. A year later Gibbs and Conover applied for U.S.P. 1,285,117, claiming the use of the same type of catalyst at between 350 and 550°C. In the following years a great many patents relevant to this particular catalyst system were filed; a useful list of these will be found in the section on phthalic anhydride in the article dealing with PHTHALIC ACID in *Thorpe's Dictionary of Applied Chemistry* (fourth edition, 1949, Vol. 9, 604). The origins of the fluidised-catalyst method can be traced back to the 1928 patent of W. A. Caspari (U.S.P. 1,674,589), which described the use of finely divided vanadium pentoxide catalyst, which was suspended in the gas stream, for the preparation of phthalic anhydride.

In the inter-war period, large-scale production of phthalic anhydride depended on vapour-phase oxidation carried out in fixed-bed plants. The technical details of this method of working the vapour-phase oxidation process were published after World War II in four reports of intelligence teams that examined the German chemical industry. These reports[4] describe in detail the I.G. phthalic anhydride plants operating at Uerdingen, Ludwigshafen and Schkopau. These plants used naphthalene of hot-pressed quality. The proportion of naphthalene in the air mixture fed to the reactor was 0.63 molar per cent, i.e., well below the explosive limit for such mixtures. The feed-rate was about 244-286 lb./hr. of naphthalene. The crude product required to be purified, and this was done by a *batch* process. I.G. obtained an overall yield of refined phthalic anhydride of about 80% of theoretical.



In Britain this chemical was being produced—to the tune of around 10,000 tons in, say, 1946—in similar fixed-bed plants. The major producers were then Monsanto (at Ruabon) and I.C.I. (at Grangemouth and Huddersfield). Since that time only one major fixed-bed plant has been erected in Britain—the Monsanto extension at Ruabon, which started operating in 1955. With that one exception, all effort has been concentrated on fluidised-catalyst units. Fig. 1 corresponds to a typical unit of this type. All fluidised phthalic anhydride units have followed this pattern, though the first of them—the Sherwin-Williams plant—differed by having a somewhat sloping heat exchanger. (The vertical heights of the various reactors have been of the same order of magnitude, but the horizontal dimensions—e.g., the diameter—have varied according to the capacity (*see* Table 1).

* The pattern of present use of phthalic anhydride in the U.S.A. is as follows, according to Riley[1]: alkyd resins (modified and unmodified), 52.6%; phthlate esters, 36.8%; styrene, alkyd and polyester resins, 4.6%; dyes, 2.4%; other uses, 3.6%. No corresponding figures for British usage have been published, but presumably the pattern is similar.

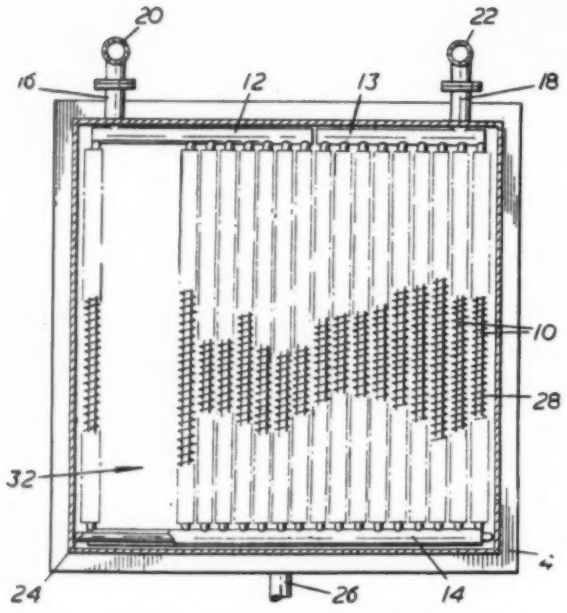


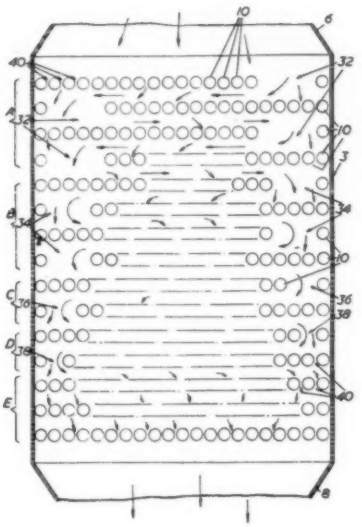
Fig. 2 (above). Section across phthalic anhydride condenser. Fig. 3 (right). Phthalic anhydride condenser showing layout of the tubes.

The plant of the Sherwin-Williams Company has been described by Lee.[5] This is a relatively small unit, but this firm chose the same fluidised process for its $1-million expansion in 1952. Sherwin-Williams encountered plenty of difficult design and operational problems on its initial plant. The trickiness of those problems is indicated in one American report[6] (published in February 1956), which stated that Sherwin-Williams was the only U.S. manufacturer that had succeeded in making the fluidised process go. Accordingly to Riley,[1] the fluidised unit built for American Cyanamid at Bridgeville, Pasadena, "went through an agonising shake-down period, and it is doubtful even now that all the kinks are out". In the same S.C.I. lecture, Riley commented that the performance of fluid-bed processes in chemical (rather than petroleum) plants has soured some early and ardent enthusiasts of the technique, though he summed up his own considered opinion in these terms: "*It is a versatile technique that can be useful in many places. One lesson is clear: trouble at the start doesn't necessarily mean that the process is a failure.*" This lesson has been driven home by experience gained on the Sherwin-Williams plant and subsequent phthalic anhydride plants, and also on such units as du Pont's fluid-bed plant for making titanium tetrachloride.

Riley stressed in his lecture that, while the design and operation of fluid-bed units is by no means as simple as was once supposed, it must be realised that the problems which have arisen during attempts to operate commercially such large plants can be solved. *The growing demand for phthalic anhydride can most probably only be met by large fluid-bed plants.*

The fluidised phthalic anhydride plant built by Foster Wheeler Ltd. at the Orgreave Works of United Coke & Chemicals Co. Ltd., Rotherham, has been operating for about four years. More details have been released (in Riley's S.C.I. lecture) about this plant than any other similar plant in Britain. Many interesting details specifically relevant to the Orgreave plant can be extracted from the patent literature.[7] As indicated in Table 1, the design of this plant has many features in common with that of the Sherwin-Williams plant; for this reason the reader should consult the important paper published in *Petroleum Refiner*[8] by R. F. Ruthruff, who was retained by United Coke & Chemicals during the initial stages of the designing and erection of the Orgreave plant. (The Sherwin-Williams plant design derived from the earlier work of the Standard Oil Development Company described in B.P. 568,913 (1941)).

A large part of Riley's S.C.I. lecture was devoted to the filtration system[7] developed at Rotherham. The reason why an efficient filtration system is essential is, of course, that one cannot afford to waste the expensive catalyst; any catalyst that gets into the exit gases must be removed by filters. Moreover, vanadium pentoxide would constitute a health hazard if it were allowed to escape with the exit gases. Porous ceramic filters and porous stainless-steel filters have been tried for this specific purpose. The former kind of filters need to be relatively thick-walled in order to withstand severe mechanical and thermal shocks; a battery of stainless-steel filters would be very expensive. Both kinds of filter carry the disadvantage that it is difficult to assess what their *useful* life would be. For these reasons, the Orgreave team developed a filter that is constructed by wrapping layers of glass cloth, glass-fibre mat and glass tape on a perforated steel tube. This kind of filter



(Fig. 4) is described in detail in B.P. 713,560 (1954). Four years of operational experience have established the value of these filters; one snag, according to Riley, is the brittleness of the glass fibres, which must not be subjected to excessive pressures or sharp blows; he stresses the necessity of handling these filters with care. The pressure drop across a battery of these filters is between 2 and 3 lb./sq. in. These filters can be operated at temperatures in the 450-500°C region. Riley[1] suggests that similar filters could be used at a much higher temperature if woven cloths and mat of Refrasil (which withstands 1000°C) were used.

The Condensation System

The usual method for condensing phthalic anhydride from the product gas steam depends on the use of "barns" or "hay boxes", but this is far from satisfactory. In the U.S.A. tubular heat exchangers working in parallel have been used instead, but where this method has been adopted it has been found necessary to back the tubular condensers with one or more barns downstream. Originally, the deeign of the Orgreave plant included two large tubular condensers, but during the initial stages of commissioning it was realised that these condensers left much to be desired. This led to the decision to investigate the possibility of

designing a system free from all these objections. This investigation was guided by three principles. Firstly, it was decided that the system must be such that operational troubles due to corrosion, leakages, blockages, dirty heat exchange surfaces, etc., could be rectified without a major shut-down of the plant; secondly, the system must be intrinsically safe and free from the risk of explosions; and thirdly, the system should use the type of heat exchangers employed in air conditioning. The air-conditioning industry is highly competitive: the heat exchangers used are efficient and not costly.

In the Rotherwood Laboratories of United Coke & Chemicals a small pilot phthalic anhydride plant (with a 4-in. diameter reactor) had been constructed. Initially, this included a small barn for condensing the phthalic anhydride. This was replaced by a new type of condenser.[7] A number of small, flanged, rectangular cases, approximately 6 in. × 4 in., each containing either one or two banks of three spiro-gilled tubes, were made by the Spiral Tube & Components Co. Ltd., of Osmaston Park Road, Derby. A number of these cases were bolted together to form a condenser having some 10 to 15 banks of spiro-gilled tubes. Conical ends were fitted and the whole unit connected to the product line of the pilot plant. Water at 40°C was passed through the gilled tubes. The product gases entered the condenser at approximately 180°C and issued at a temperature only a few degrees above that of the cooling water. This condensing system proved to be extremely efficient. Eventually eight of these condensers (Figs. 2-3), working in parallel, were installed on the plant. This number proved convenient when changing over in sequence from condensing to melting; thus, one can work a number of different cycles, e.g. five units condensing with three units melting, or six units condensing with two units melting, at any one moment. It is considered that the close packing of the gilled tubes in the condensers eliminates any possibility of an explosion occurring. (For safety, each unit is provided with two explosion doors.)

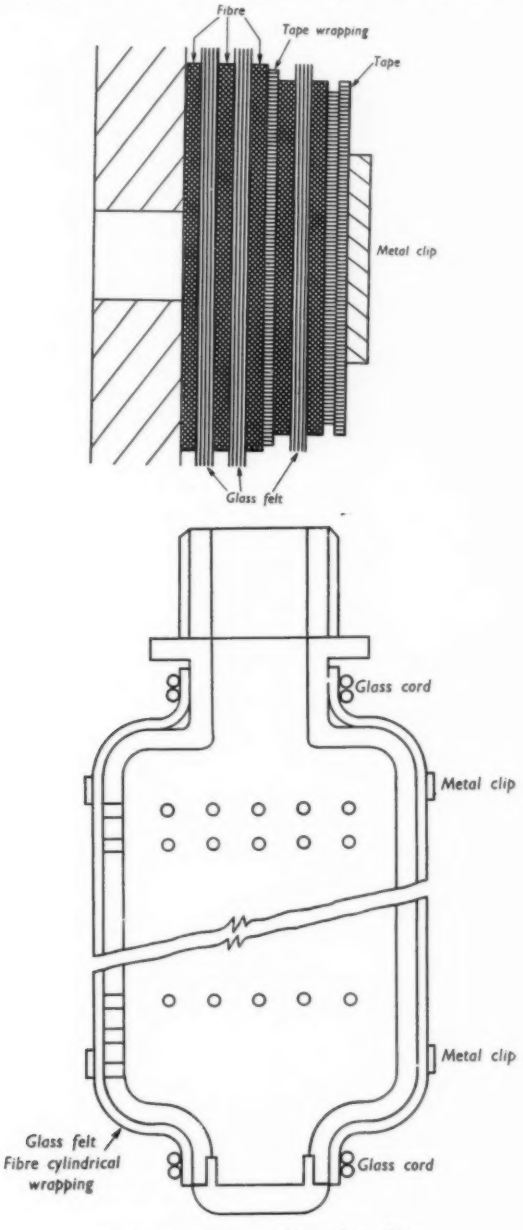


Fig. 4. Structure of fibre-glass filter.

In the Orgreave plant, cold-tempered oil is used for condensation (at about 40°C) and hot oil (*c.* 180°C) for melting. The molten phthalic anhydride which is produced is pumped to a distillation unit, thereby eliminating the problems that arise in its manual transfer.

The condensation installation is practically perfect, and it does not need to be backed by barns. The effluent gases from the condensers pass directly to a scrubbing tower before being released to the atmosphere; so little phthalic anhydride leaves the condensers that it is possible to economise on the scrubbing water by re-circulating wash water. As a result, the volume of effluent leaving the plant (through a bed of limestone chips) is reduced to a minimum. This condenser installation has proved efficient in operation over a period of more than two years.

Percentage Yield

The percentage yield of phthalic anhydride at Orgreave is about 95% of theoretical. The Orgreave plant has established that it is possible to work a large fluidised-catalyst plant and produce phthalic anhydride that is substantially free from both maleic anhydride and naphthaquinone and in yields appreciably higher than those obtained with fixed-bed plants.

Practically no details have yet been given about the system for cooling the reactor of the Orgreave plant. In fixed-bed units a variety of coolants have been used, including mercury, sulphur, sundry molten alloys, and mixtures of sodium nitrate/nitrite (U.S.P. 1,936,610 and 1,945,812). The removal of the heat of reaction by means other than through a conventional heat-exchange medium has been patented: such methods include (i) the use of excess air; (ii) injection of water sprays into the catalyst zone; (iii) admixture with the air of an inert material (e.g., carbon tetrachloride).

In the Sherwin-Williams plant a tubular heat exchanger is located below the reactor; through it circulates the fluidised catalyst from the reactor, and the catalyst is thereby cooled before being returned to the reactor.

REFERENCES

[1] Riley, H. L. "The Manufacture of Phthalic Anhydride by the Fluidised Catalyst Method", S.C.I. Chemical Engineering Group lecture, November 13, 1956 (to be published in *Chemistry and Industry*).
[2] Shreve, R. Norris. *The Chemical Process Industries*, McGraw-Hill, second edition, 1956, 884. Section on the production of Phthalic Anhydride.
[3] *Chemical Week*, 1955, **77** (September 3), 71; *Chem. Eng. News*, 1955, **33** (October 31), 4684.
[4] C.I.O.S. File No. XXVII—80; No. XXVII—85; No. XXVIII—29; B.I.O.S. Final Report No. 753.
[5] Lee, J. A. *Chem. Met. Eng.*, 1945, **52**, No. 7, p. 100.
[6] *Chemical Week*, 1956, **78** (February 11), 74.
[7] Riley, H. L., and Norris, J. United Coke & Chemicals Co. Ltd., B.P. 713,560 (1954). Riley, H. L., Coates, R. G., and Norris, J. United Coke & Chemicals Co. Ltd. B.P. 751,352 (1956). The first patent deals with the filter system, the second with the condensing system.
[8] Ruthruff, R. F. *Petroleum Refiner*, 1953, **32**, October issue, 113.

ATOMIC ENERGY PRESENTS

THE CHEMICAL ENGINEER WITH NEW PROBLEMS

by K. L. STRETCH, M.A., LL.B., A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E

Many new problems of great chemical engineering interest have arisen in the design, commissioning and operation of the Calder Hall power station.* New standards of perfection have had to be achieved and maintained; new testing and inspection methods have had to be designed. These aspects of the world's first industrial-scale atomic power plant are discussed by the Works Manager of Calder Hall.

THE main peculiarity of the Calder reactors compared with other existing nuclear reactors is that at Calder the heat released by the fission process, instead of being wasted, is utilised for the generation of electrical energy. These reactors are gas-cooled, so it is necessary to pressurise the cooling circuit to enable this heat to be extracted efficiently (as the power needed for this purpose varies as the inverse of the square of the absolute pressure), and many of the problems which have arisen at Calder have been due to the necessity for a pressure circuit. This applies particularly to the problems involved in getting anything—gas or solid—into or out of the reactor; the difficulties are accentuated because of the fact that the pressure vessel itself will not normally be closely approachable, due to the radiation associated with the reactor and its shell. It is worthwhile considering some of these problems and how they are being dealt with at Calder.

Testing the Pressure Vessels

In the first place, the fabrication and maintenance of the pressure vessel itself poses some entirely novel problems because of its inaccessibility in service. As many of the normal inspection techniques and maintenance operations are not applicable, it was essential to provide a pressure shell of the greatest reliability. This was carried back to the very earliest stages of the fabrication, when every piece of plate used was supersonically tested before being accepted for shaping and welding into position. The vessel was fabricated on site from shaped pressed sections delivered from the works, and every inch of butt-welding carried out on the shell was X-rayed before acceptance.

When the vessel had been fabricated and stress-relieved *in situ*, a very stringent testing programme was adopted to ensure that the design was satisfactory. The vessel was extensively covered with strain gauges at all likely points of high strain and tested to 135 psig with air pressure, as a hydraulic test would have overloaded the lower portions of the structure. Throughout this test, observation on the strain gauges was carried out and, apart from some minor modifications which were recommended and implemented, it was established that there should be no undue straining of the metal of the vessel wall in service. In addition, a close watch was kept on the movement of the vessel under various conditions of pressure and temperature to make sure that expansion in the directions allowed was free and unrestricted, with no distortion of the vessel or its position taking place.

Once the vessel had been completed in position, a stringent cleaning programme was carried out on the inside walls. This was primarily in the interests of the operation of the reactor core, to ensure that no materials that were incompatible with the reactor core or that were likely to absorb neutrons were introduced. It also ensured that the surface of the metal was maintained in a condition adverse to the start of corrosion. A very thorough leak-testing programme was carried out on the gas circuits to detect and rectify any serious loss of coolant.

After the vessel had been tested and taken into service, a number of operational techniques were adopted to ensure that the vessel is not put to any undue strain. This power station was designed as a base-load station, and it is therefore possible to maintain a very slow rate of temperature change when raising load. This is very thoroughly monitored by a large number of installed thermocouples, thereby ensuring that unnecessary strain is not put on the vessel by rapid and frequent thermal cycling. In fact, as the vessel is run as a constant temperature difference device, and as it is hoped that in practice the operational runs will be of the order of months, the vessel should pass through an abnormally low number of thermal cycles in its lifetime.

A very strict watch has to be kept on the purity of the circulating gas, so that the carbon dioxide should not adversely affect the vessel metal to any significant extent. The main problem here is to ensure that no contaminants get inside the reactor circuit. The less usual ones are guarded against by the normal methods of chemical analysis before any batch of coolant is accepted, but against the obvious danger of a leak in a heat exchanger introducing water to the circulating system, installed dew-point recorders provide a constant guard and warning which make it possible to shut-down the reactor immediately. Moreover, there is very strict control of the quality of the boiler feed and circulating water, which reduces the chances of tube corrosion. Although the steam conditions are low by modern standards, it is aimed to hold the return feed-water to an oxygen content of less

*A general account of the design and operation of Calder Hall was published in *British Chemical Engineering*, October, 1956, pp. 318-23.

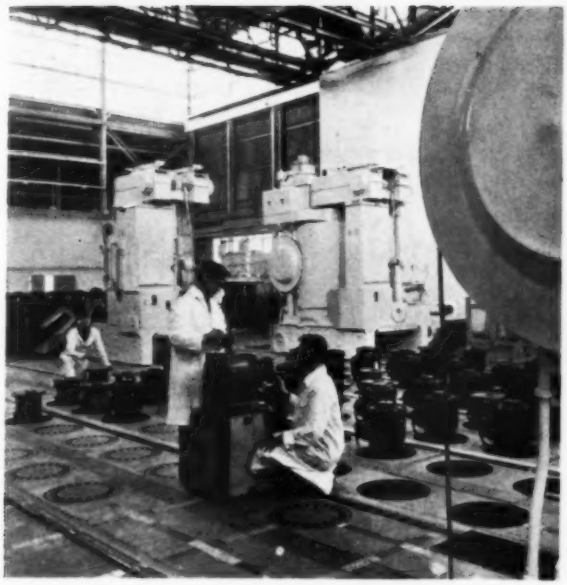


Fig. 1. The charge-discharge deck of No. 1 reactor of the Calder Hall "A" atomic power station. Rear left can be seen a lightly shielded charge machine and, rear centre, a heavily shielded discharge machine, devices used to insert new fuel cartridges and remove highly radioactive spent cartridges from the reactor.

than 5 ppm. The installed driers are quite capable of handling such small traces of moisture as are introduced with the carbon dioxide charge and any steam leakage held below 2.5 lb/hr, so the possibility of an even mildly corrosive gas condition arising is very low.

Position indicators are liberally deployed around the reactor and its circuit; constant watch on these will give an immediate indication if there is any peculiar distortion associated with their movement.

As normal inspection facilities are not available (because of the activity of the metal even long after shut-down), an attempt is being made to work out suitable alternative inspection procedures which will detect any deterioration in the fabric of the vessel. Special viewing facilities have been provided; in particular, a television camera has been developed which enables detailed examination to take place in areas of the reactor where the irradiation is so high that direct visual inspection is not possible (Fig. 5). To monitor the condition of the actual metal of the reactor itself, a large number of steel specimens have been machined to size for testing, and these are inserted in suitable carriers inside the reactor where they are exposed to the same temperature, gas and flux conditions as the main wall of the vessel. These pieces are cut from both the plate and the weld metal, stressed and unstressed, machined for the normal tensile and bend testing. Sufficient specimens have been installed to enable a number of samples to be taken out of the reactor at regular intervals corresponding to normal inspection periods. It is hoped that the examination of these, together with the viewing facilities that have been provided, will enable an accurate picture of the condition of the vessel to be obtained. This is particularly necessary for the first Calder reactors, as a knowledge of the behaviour of steel under these conditions has yet to be acquired.

The Graphite Lattice

One needs to know that the pressure vessel is safe and sound; in addition, it is essential to maintain very strict control over the graphite in order to secure efficient operation of the reactor. Before erection, a very strict specification was set to maintain the quality of the raw blocks which are fed into the machining line. Throughout the machining and laying of graphite, extremely tight standards of mechanical tolerance and cleanliness were maintained. The reactor core stands as a solid block independently of the vessel walls, and it is therefore essential to have position indicators, which enable a continual watch to be kept so that any movement or distortion of the graphite lattice, which may be caused by irradiation or temperature, can be recorded.

A considerable number of graphite specimens are inserted into the reactor; these can be removed at intervals

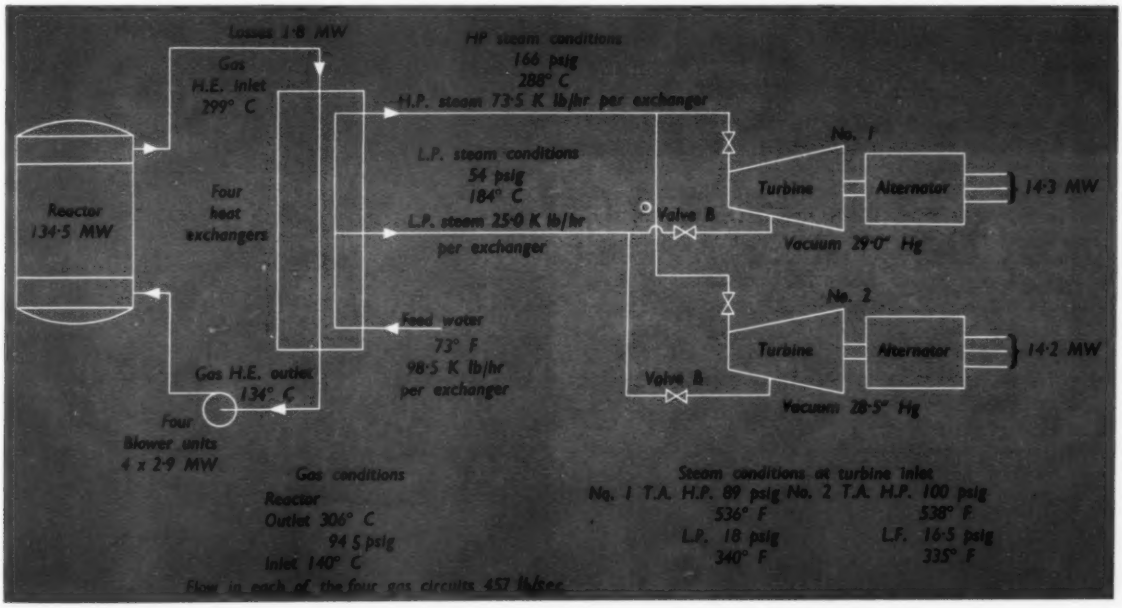


Fig. 2. Heat balance indicating how the reactor was originally stabilised.

Fig. 3. A Calder Hall fuel element.

and examined to find out whether any modification in structure has occurred. The usual strict monitoring of both gas analysis and temperature during all phases of operation of the reactor immediately detects any peculiarities in its behaviour.

Arrangements are also provided by means of an auxiliary blower for annealing the graphite mass, should it be found by examination of the specimens that any dangerous stresses have been built up in the lattice.

Carbon Dioxide

Control of the purity of the carbon dioxide is important. This ensures no deterioration of the vessel or graphite occurs; it also prevents gradual build-up in the reactor of any objectionable material (i.e., anything which is incompatible with the other materials, particularly the fuel elements, or which will absorb neutrons). In particular, one needs to guard against *a high argon figure*, as this would result in building up a high activity in the circulating coolant gas and so create difficult problems of shielding in the operating areas. This difficulty is greater in Calder than in reactors where once-through cooling is used; the continual and rapid recycling of the coolant (about three times a minute) allows isotopes with a long half-life to build up to high activities.

In addition, when a release of coolant takes place, it is, of course, essential to ensure that no hazard will arise to involve people either inside or outside the works' fence. Before release, all gas is both filtered and monitored. Evidence to date indicates that with any normal release neither the radioactivity nor the chemical hazard possible from carbon dioxide is likely to approach a figure which might present a health hazard; in fact, at the present moment the indications are that any such effect will scarcely be detectable.

Besides these special precautions, there is continual monitoring of the reactor, both for carbon dioxide leakage and radiation, to make sure that there is no hazard from either of these effects in any part of the plant.

Fuel Elements

A photograph of one of the Calder fuel elements is reproduced in Fig. 3. The element itself consists of natural uranium encased in a canning material (a magnesium alloy). This has been selected as a metal which has favourable nuclear characteristics, as it is a very low absorber of neutrons. The cans, which are machined out of solid bar, carry helical fins along their entire length (see Fig. 3); this arrangement improves the heat-transfer properties of the elements, and enables a high heat rating to be obtained from the uranium without having to run it at temperatures which might cause distortion of the fuel-element structure.

With this type of fuel element, it is clear that the temperature limitations imposed on the circuit by the creep properties of the metals involved and the necessity for avoiding undue thermal cycling (which might lead to fracture of the cans) sets a tight limit on the operational efficiency of the station. At Calder Hall at the present moment a limitation of 400°C on the can temperature is being observed, but clearly this is a figure which is subject to continual improvement and long-term proving.

In addition, the long-term structural stability of the element under irradiation will be a major factor in determining the discharge cycle of the reactor. As it is necessary to shut-down the reactor and de-pressurise whenever a discharge takes place, it is clearly desirable to push up the

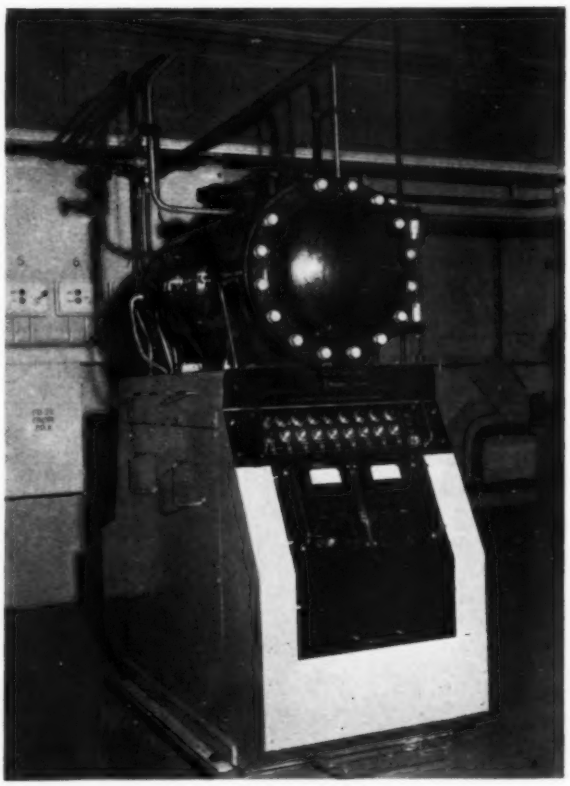


Fig. 4. Precipitator unit of the "sniffer" apparatus in the Calder Hall burst-slug detector control room.

time between consecutive discharges to the maximum possible. Operation of the reactors will therefore always be pushing hard against the metalurgical limitations imposed by the structure of the fuel elements.

Burst-cartridge Detection Gear

Particularly in view of the fact that it will be necessary to work to the metallurgical limits of the elements, it is essential to have an accurate means of detecting when any of the fuel elements fail. Here, again, the recycling of coolant means that any radioactivity gradually builds up in the reactor circuit instead of being swept away, and makes it imperative that any source of contamination should be detected and removed at the earliest possible opportunity. Detection is done by the burst-cartridge detection gear. A picture of the precipitator connected with this circuit is shown in Fig. 4. The basic principle on which this works is as follows: a sample of gas is drawn from each fuel channel in turn and passed through a precipitator where any radioactive material is deposited on a wire; this wire is then moved in front of a scintillator which counts the activity it deposited on it.

Clearly, the limiting factor in the sensitivity of this instrument is the signal-to-background ratio. This is maintained at a high figure by three main checks. In the first place, a very high degree of cleanliness and inspection is maintained at Springfields to ensure that cartridges delivered to Calder carry negligible amounts of surface contamination. When they are received at Calder and charged into the reactor, a check is made over the whole of the charged zone to ensure that no badly contaminated elements have managed to slip through the inspection net. Lastly—and this is most important from the operational point of view—a very strict control of everything passing into the reactor is maintained to ensure that no impurities are introduced. The most difficult impurity to deal with is *argon*, which, on passing round the circuit, can build up to a fairly high activity—due to the long half-life of the active argon isotope. To ensure that this does not reach unmanageable proportions, a very strict control of the purity of the ingoing carbon dioxide is maintained, so that the argon build-up in the reactor is minimised.

Operating Conditions

After charging the reactor and carrying out the necessary proving tests, the reactor was allowed to work up to a moderate power in readiness for the official opening. Fig. 2 is a flowsheet indicating how the reactor was stabilised off at a safe moderate condition which could be maintained until the official opening was over. This does not correspond by any means to either the full or the most efficient method of operating the system; but, as modification of the trim of the reactor must be based on long-term observations and can only be conveniently phased-in with the charge and discharge cycles, no attempt was made to extract the maximum amount of power from the reactor until a later stage. Moreover, it must be remembered that Calder was designed primarily as a plutonium-producing unit, so the plant has been optimised to give *maximum plutonium output*, which is related to total heat output rather than to the maximum efficiency in the conversion of heat into electrical power.

As our primary concern is with plutonium production, we have to keep a very close watch on the flux distribution in the Calder reactor, in order to obtain an accurate estimate of the build-up of plutonium. This is necessary in any form of reactor merely for operational control, but it is even more important where a tight specification is placed on the plutonium produced.

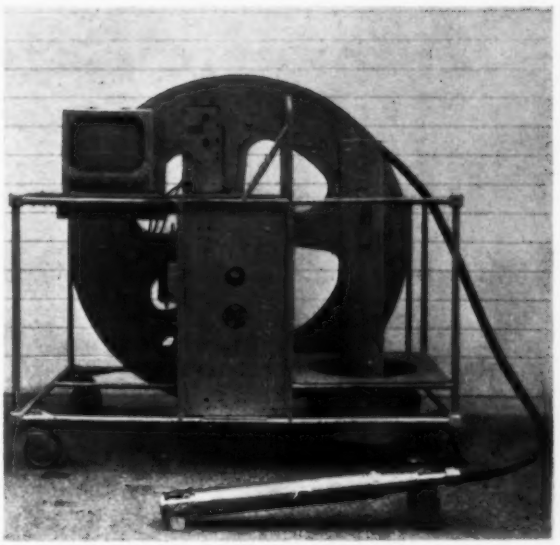


Fig. 5. The TV camera, specially designed by Pye for the A.E.A., is seen in foreground. Behind it is trolley carrying the monitor and control unit.

Fig. 1 shows a picture of the flux-plotting apparatus in operation. A wire is run down into the reactor, irradiated for a given time and then withdrawn and its radioactivity counted. This enables a measure of the flux at selected points in the reactor to be obtained, and from this an accurate picture of flux distribution is drawn up. With a knowledge of the flux to which the elements have been exposed and the accurate record which is kept of the charge and discharge of every element, it is then possible to forward reasonable estimates of the plutonium build-up in any set of fuel elements which are withdrawn from the reactor for dispatch to the Windscale Works.*

The flux plots which are obtained from these measurements are also used to check two other factors that are important to the safe and efficient operation of the reactor. The first is the measurement of can temperature; the second the maintenance of a high enough outlet-gas temperature to keep the thermal efficiency of the station as a power generator satisfactory.

The temperature of a number of cans is measured by thermocouples and is either recorded or indicated in the control room. Except for some special start-up thermocouples, measurements are only possible on the top cartridge in each channel, so it is essential to be able to calculate the temperature of the hottest can. While an effort is made to place the thermocouple cartridges in the channels that are likely to run hottest, it is also necessary to check whether one has, in fact, done so. The correlation of the series of spot temperatures with the flux plots across the pile enables a complete picture of the power release and temperatures throughout the reactor to be built up; this enables an accurate assessment to be made of the difference in temperature between the hottest can and the hottest measured can, so that the maximum can temperature condition is strictly observed.

The flux plots and temperature recordings also enable those areas which are running cold (which reduce the thermal efficiency by degrading the outlet-gas temperature) to be identified. Steps can then be taken at a shut-down to alter the pattern of the charge with a view to improving the operational efficiency.

*The process of plutonium extraction was described in the article "Chemical Engineering Achievements at Windscale" by G. R. Howells, *British Chemical Engineering*, May, 1956, pp. 8-11.

ABSORPTION OF CARBON DIOXIDE IN SOLUTIONS OF DIETHANOLAMINE

D. R. MORRIS, B.Sc. Ph.D.,* and S. B. WATKINS, M.Sc., F.R.I.C., M.I.Chem.E.*

The increasing use of aqueous solutions of organic amines as absorbents of carbon dioxide gas has prompted further investigation of the rates of absorption. The rates have been measured using the standard disc-column, and a satisfactory correlation of results has been obtained on the basis of a modified van Krevelen-Hoftijzer equation.

THE advantages of using aqueous solutions of amines lie in the fact that amine solutions (by contrast with caustic-alkali solutions) may be regenerated by the application of heat, and may then be recycled to the absorption columns. Alkali carbonate solutions may also be employed as absorbents, but these have not so great a capacity for absorbing the acidic gas as organic amine solutions.

The industrial uses of aqueous amine solutions for absorption have been discussed by Bottoms,[1,6] Storrs and Reed[22] and by Reed and Wood.[16] The rates of absorbtion for various amine solutions have been measured by several investigators,[8, 10, 12, 13, 20] the most comprehensive being those of Cryder and Maloney[8] using aqueous solutions of diethanolamine, and their $K_G a$ values are of the same order of magnitude as the earlier results of Hirst and Pinkel.[13] They also present the recalculated data of Gregory and Scharmann,[10] on the rate of absorption of carbon dioxide in solutions of monoethanolamine and di-aminoisopropanol under pressure.

The experimental investigations of Cryder and Maloney[8] were carried out on a pilot-plant scale, using an 8-in. diameter tower packed to a depth of 16ft with ¾-in. Raschig rings. The overall coefficient, $K_G a$, expressed in gas concentration units, was found to be substantially independent of the gas rate and to increase with increasing liquid rate in a manner typical of controlling liquid-phase resistance, as pointed out by Sherwood and Pigford.[19] The coefficient varied with the concentration of unreacted amine, in the expected manner, increasing with increasing amine normality below about 3*N*, but decreasing slightly with increasing amine concentration above this normality, owing to the increase in liquid viscosity. The coefficients were also found to decrease with increasing carbon dioxide partial-pressure. Sherwood and Pigford also point out that this behaviour is probably associated with the second-order reaction between the dissolved acid gas and the alkaline amine. It is similar to that found by Stephens and Morris[21] for chlorine absorption in ferrous chloride solution.

The results of Cryder and Maloney have been confirmed in a general way by Shneerson and Leibush,[20] who used a 1-in. diameter column filled to a depth of 13.8 in. with 5 to 6-mm glass rings. The absolute results of Shneerson and Leibush are probably unsuitable for design work owing to the relatively large ratio of wall surface-area to packing area involved in their elaboration. These investigators also report[11] that the rate of absorption of carbon dioxide in monoethanolamine solution is 2 to 2.5 times greater than the rate of absorption of the gas in a diethanolamine solution of equal normality, other variables also being equal. The monoethanolamine solution, however, is less easily regenerated.

SYMBOLS USED

A. *Dimensionless Quantities*

Sh = Sherwood number $\left[\frac{k'_L}{D}\left(\frac{\mu^2}{g\rho^2}\right)^{\frac{1}{3}}\right]$

Re = Reynolds number $\left[\frac{4\Gamma}{\mu}\right]$

Sc = Schmidt number $\left[\frac{\mu}{\rho D}\right]$

Ha = Hatta number $\left[\frac{\left(\frac{\mu^2}{g\rho^2}\right)^{\frac{1}{3}}\cdot\left(\frac{k_I}{D}\right)^{\frac{1}{2}}}{\tanh\left(\frac{\mu^2}{g\rho^2}\right)^{\frac{1}{3}}\cdot\left(\frac{k_I}{D}\right)^{\frac{1}{2}}}\right]$

B. *General Nomenclature*

a = area of interphase contact per unit volume of tower (ft^2/ft^3);
A = suffix referring to soluble component in gas;
c = constant;
c_{Ai} = concentration of solute at interface (lb mol/ft^3);
d = equivalent diameter for gas flow (ft);
D = diffusivity (ft^2/hr);
g = suffix referring to gas phase;
g = acceleration due to gravity (ft/hr^2);
i = suffix referring to interface;
k'_L = liquid-film coefficient for no reaction (lb/hr ft^2lb/ft^3 or molar units);
k''_L = liquid-film coefficient in presence of chemical reaction (lb/hr ft^2lb/ft^3 or molar units);
k_I = first-order reaction velocity constant (hr^{-1});
k_{III} = third-order reaction velocity constant (ft^6/lb mol^2 hr);
k_G = gas film mass-transfer coefficient based on driving force in atmospheres (lb/hr ft^2atms);
K_G = overall mass-transfer coefficient based on driving force in atmospheres (lb/hr ft^2 atms);
L = suffix referring to the liquid phase;
N = normality (gm equivalents per litre);
p_{BM} = mean partial pressure of inert component in the gas film (atms);
P = total pressure (atms);
q = concentration of unreacted solute (lb mol/ft^3);
S = surface tension (dynes/cm);
t = liquid temperature (°C);
T = absolute temperature (°K);
v = gas velocity relative to liquid surface (ft/hr);
X_{Ai} = concentration of solute at interface (lb/ft^3);
Γ = liquor rate per unit of wetted perimeter (lb/ft hr);
ρ = density (lb/ft^3 or gm/cc);
ρd = density of diffusing gas (lb/ft^3);
μ = viscosity (lb/ft hr or poises(.

* Chemical Engineering Department, King's College, University of London.

Other absorption data are limited to those published by Guyer and Purner,[12] obtained from experiments on the batchwise absorption of carbon dioxide in solutions of mono, di, and tri-ethanolamine. These results indicated that monoethanolamine gave rise to the highest absorption rates, in agreement with the findings of Shneerson and Leibush[20] as already cited. Recently, a considerable amount of work has been done on investigating the rate of absorption of carbon dioxide in amine solutions in centrifugal absorbers.[7, 9] The absorbents used consisted of concentrated monoethanolamine only and, in view of this, these investigations will not now be considered further.

Description of the Apparatus

The apparatus we employed for the determination of the mass-transfer coefficients is shown diagrammatically in Fig. 1. It consisted essentially of a disc absorption column, similar to that described and used by Stephens and Morris,[21] a steam preheater, followed by a stripping column packed with Raschig rings, inter-coolers, pumps and other auxiliary equipment.

A detailed diagram of the disc absorption column is shown in Fig. 2. It consisted of a suitable number (53) of ceramic discs suspended (with a $\frac{1}{16}$-in. stainless-steel wire) edgewise and mutually at right angles in a glass column of 1-in. internal diameter. Experiments had indicated that nickel-plated mild-steel discs were unsatisfactory as they were not completely wetted at low liquor-rates. The discs were cemented to the wire by means of a suspension of lead carbonate in sodium silicate solution, which hardened on heating. The dimensions of the discs and the column are given in Table 1, and the method of fixing the disc assembly in the column is evident from the diagram.

The liquid was supplied from a 10-l. reservoir fitted with a constant-head device, the overflow returning down the stripping column (which was not in operation) to the suction of the pump. From the reservoir, the liquid flowed through an orifice meter, the stainless-steel plate having a central hole of $\frac{3}{32}$ in. diameter and being set in a $\frac{5}{8}$-in. i.d. stainless-steel tube. The pressure tappings were located roughly one pipe-diameter and a half pipe-diameter upstream and downstream respectively. The manometer fluid was *o*-dichlorbenzene. The liquid was then fed to the absorption column *via* a tube terminating in a jet, through which the supporting wire passed, and was led away by a central tube and small funnel under the lowest disc. The rate of liquid flow was controlled by a stainless-steel needle-valve. The inlet and exit tubes were of $\frac{3}{4}$-in. bore stainless steel, the jet of the feed tube was $\frac{3}{16}$ in. and was later increased to $\frac{7}{32}$ in. because of trouble with air locks. It was located $1\frac{7}{8}$ in. above the uppermost disc. The liquid off-take tube from the base of the column was partly of rubber so that it could be raised or lowered as necessary to maintain the liquid level in the stainless-steel off-take tube near the upper end. Thus additional absorption surface from a film of liquid on the tube wall was avoided. The liquor was collected in the 10-l. flask as shown. Provision of thermometers in the inlet and exit liquor lines enabled the temperature change occurring on absorption to be recorded. A drain cock was fitted at the base of the column for the removal of any liquid which collected there as a result of splashing from the discs.

Gas Connections

The inlet and exit gas connections to the tower were of glass tubing of bore as wide as $\frac{5}{8}$ in. to minimise eddy currents in the gas caused by a sudden expansion effect. The first disc was located between 8 and 9 in. above the inlet-gas connection, this section of the tower acting as a

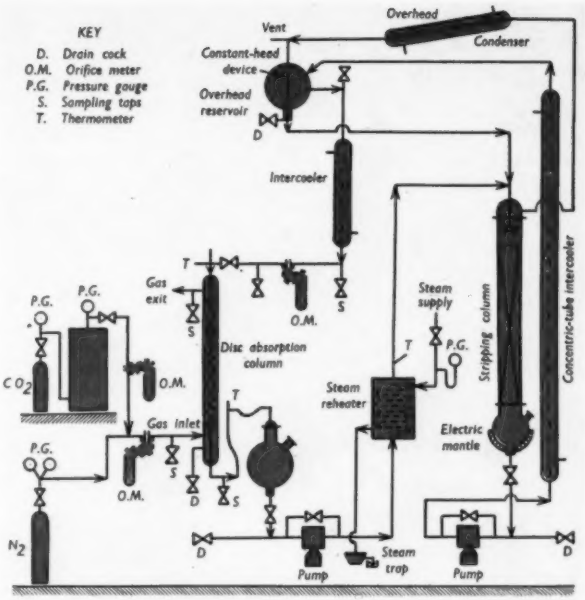


Fig. 1. Diagram of experimental apparatus.

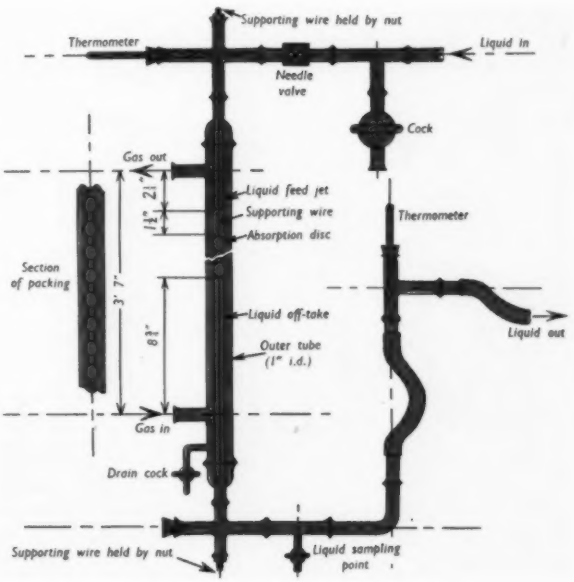


Fig. 2. Diagram of disc absorption-column.

Table 1. Dimensions of Absorption Column

Number of discs	53
Disc diameter (average)	0.598 in.
Disc thickness (average)	0.179 in.
Tube diameter	0.99 in.
Mean perimeter for liquid flow ...	0.125 ft
Equivalent diameter for gas flow ...	0.0495 ft
Free space (dry)	89%
Absorption surface*	0.331 sq. ft

** Uncorrected for film thickness or for loss of surface at points of contact, but used throughout as an approximation to the true liquid surface.*

calming section to eliminate any eddy currents in the gas stream. Constancy of the gas composition, when operating with diluted carbon dioxide, was ensured by the provision of two orifice meters—one on the carbon dioxide line, and one on the diluted-gas supply line. The brass orifice plates were drilled $\frac{1}{16}$ in. and $\frac{1}{8}$ in. respectively, and installed in $\frac{1}{2}$-in. nominal bore mild-steel pipe, the pressure tappings being located in the same relative positions as previously indicated. The fluid in the manometers was di-butyl phthalate. All orifice meters were calibrated by direct measurement. The calibration of the liquid manometer was checked occasionally to avoid errors caused by alteration in the physical properties of the liquid through changes in the carbon dioxide content.

The carbon dioxide gas was found on analysis to be more than 99.5% pure. The gas was throttled by means of a reducing valve from the cylinder pressure to about 10 lb/sq. in. in an intermediate pressure vessel, whence the flow rate to the column was controlled by means of a brass needle-valve. The diluent gas used was nitrogen, the flow rate to the column being controlled directly from the reducing valve, provision of an intermediate pressure vessel being unnecessary owing to the absence of any appreciable cooling effect on expansion from the cylinder pressure. The exit gases from the column were vented to the atmosphere. Liquid and gas sampling taps were fitted as shown in Figs 1 and 2.

The steam-heated liquid preheater consisted of a mild-steel cylinder 1 ft in diameter by 18 in. high containing approximately 20 ft of $\frac{1}{4}$-in. i.d. stainless-steel tubing in the form of a coil having a heating surface of nearly 3 sq. ft. The steam pressure was controlled with a needle-valve, the whole assembly being lagged with asbestos rope. The unit was fitted with an alcohol expansion-type steam trap.

The stripping unit consisted of a packed glass column, reboiler and condenser. The column was 4 in. in diameter and packed to a height of 6 ft with $\frac{1}{2}$-in. porcelain Raschig rings, and was fitted with a stainless-steel spray distributor for the incoming liquid. The reboiler comprised an electric cradle rated at 1.5 kW fitted round the flask at the base of the column. The condenser-cooler, fitted on the gas line from the stripping column, was of glass and of the double-tube type. Its overall length was 3 ft, and it provided a heat-transfer surface area of just over 1.8 sq. ft.

The inter-cooler, fitted for cooling the liquid after regeneration, was of the concentric-tube type and consisted of three 10-ft lengths of $\frac{1}{2}$-in. o.d. stainless-steel tubing jacketed with $1\frac{1}{2}$-in. nominal bore mild-steel pipe, giving a cooling-surface area of nearly 4 sq. ft.

Reciprocating pumps were employed for circulating the liquid and they were fitted with by-passes which could be throttled with stainless-steel needle-valves. The first pump fed the rich liquor, during the regeneration process, from the base flask of the absorption column *via* the preheater to the stripping column, where the dissolved carbon dioxide was removed from the amine solution by heat and an ascending stream of air or nitrogen. The second pump cycled the hot, clean liquor from the base of the stripping column through the concentric tube inter-cooler to the overhead reservoir, whence the liquor could either be returned to the suction of the first pump, to repeat the process, or be taken off to a storage tank. The second pump was also used for maintaining the overhead reservoir full of liquid during absorption tests.

In constructing the apparatus care was taken to avoid the use of zinc, aluminium, copper or their alloys where contact with the amine solution would occur.

Analysis Apparatus

Estimation of the carbon dioxide content of the solutions was carried out gravimetrically as recommended by

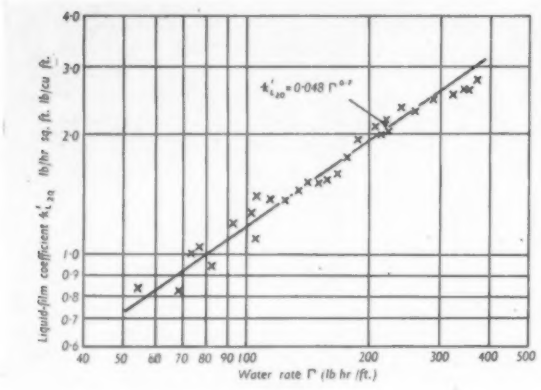


Fig. 3. Characteristics of the disc column. Liquid-film coefficients for the system CO_2—water. Values corrected to a temperature of 20°C.

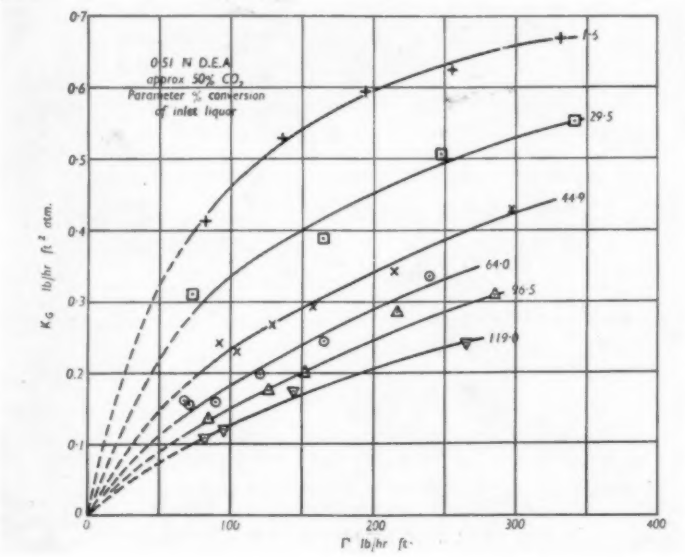


Fig. 4. Overall mass-transfer coefficient against liquor rate for inlet gas concentration 50% CO_2.

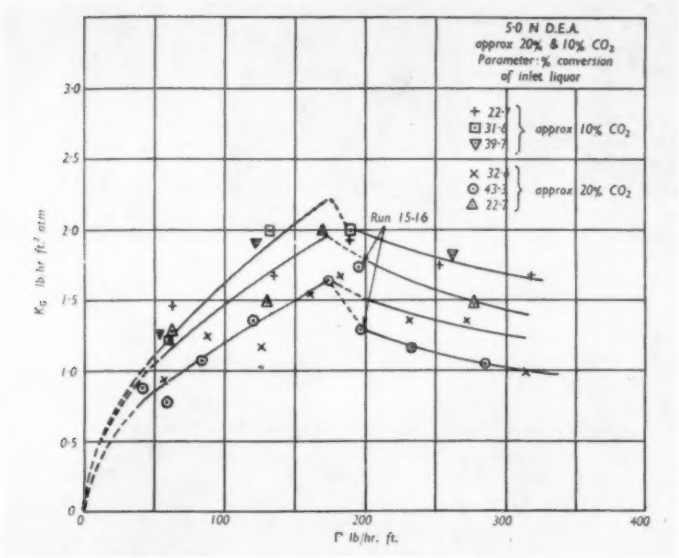
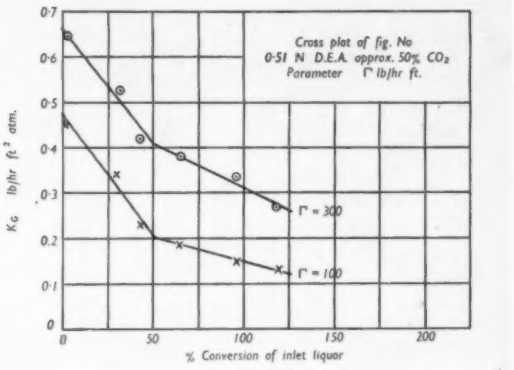


Fig. 5. Overall mass-transfer coefficient against liquor rate for inlet gas concentration of 10% and 20% CO_2.

Fig. 6. Typical results of plotting mass-transfer coefficients against inlet liquor.



Mason and Dodge.[15] A gravimetric method was also used by Cryder and Maloney[4] in conjunction with a Beckmann *p*H meter. The method consisted essentially of expelling the carbon dioxide from a known volume of solution and absorbing the dry gas in Carbosorb contained in a U-tube. From the weight change of the U-tube, the carbon dioxide content of the solution could be calculated. This method of liquid analysis was found to give accurate and reproducible results and, though rather tedious, was used throughout for the determination of the carbon dioxide content of the solutions.

The gas analyses were caried out using a standard Orsat apparatus in conjunction with the two orifice meters installed in the gas lines as already described.

Calibration of Disc Absorption-column

(A) With respect to the liquid film

The column was operated using distilled water as the absorbent for carbon dioxide to establish its characteristics with respect to the liquid film. This was done as Stephens and Morris[21] had found that different installations of apparently identical dimensions varied by about ±10% at the same wetting rate.

The liquid-film coefficient, equal in this case to the overall coefficient, was calculated from the mass of carbon dioxide absorbed divided by the interfacial area times the log. mean concentration difference between the equilibrium and the actual concentrations of dissolved gas in the liquid at the ends of the column. The coefficients were corrected to a temperature of 20°C by means of the relation given by Sherwood and Holloway[18]:

$$k'_L \propto e^{0.023t} \qquad \ldots\ldots(1)$$

The experimentally-determined absorption coefficients are shown as a plot of K'_{L20} versus Γ in Fig. 3. The results are seen to agree closely with those of Stephens and Morris,[21] who gave the following empirical equations for the results.

$$k'_{L20} = 0.048\,\Gamma^{0.7} \qquad \ldots\ldots(2)$$

$$\frac{k'_{L20}}{D} = 21.0\left[\frac{4\Gamma}{\mu}\right]^{0.7}\cdot\left[\frac{\mu}{\rho D}\right]^{0.5} \qquad \ldots\ldots(3)$$

Stephens and Morris[21] also discovered that the exponent of the Reynold's number $\frac{4\Gamma}{\mu}$ dropped to 0.5 below a Re no. of 60 when physical absorption experiments were conducted with liquid of high viscosity.

(B) With respect to the gas film

In view of the excellent agreement obtained with the results of Stephens and Morris[21] with respect to the liquid film, and, as previous investigators of the absorption of carbon dioxide in aqueous solutions of the organic amine had demonstrated that the rate of absorption was controlled by the liquid film, it was decided that the relation obtained by Stephens and Morris with respect to the gas film could be used without carrying out additional experiments in the column to be used. From experiments on the absorption of ammonia in water[21] and the vaporisation of water and of carbon tetrachloride into air,[17] the following equation has been derived:

$$\frac{k_G.P}{v\,\rho_d} = \beta\left[\frac{vd\rho}{\mu}\right]^{-0.33}\cdot\left[\frac{\mu}{\rho D}\right]^{-0.56}\cdot\frac{P}{\rho_{BM}} \qquad \ldots\ldots(4)$$

$$\text{where } \beta = 0.093\,\Gamma^{0.13} \qquad \ldots\ldots(5)$$

In the experiments here reported, the above relation was used to correct the experimentally determined coefficients for the gas-film resistance. Actually, it was found that in all cases the gas-film resistance was an entirely

negligible proportion of the overall resistance and could be neglected.

Use of the Disc Column

To investigate fully the dependence of the rate of absorption of carbon dioxide in diethanolamine solutions on the various operating variables, experiments were performed over the following range:

Normality of amine ...	0.51 to 5.0 *N*
CO_2 content of gasstream	10% to 100%
Liquor rate	40 to 300 cc/min.
Degree of conversion of amine to amine carbonate	From zero to the degree of conversion at which the back pressure of CO_2 from the solution was apparent as shown by the equilibrium charts

The effect on the rate of absorption of varying the gas rate was not investigated, as this variable had been shown by Cryder and Maloney,[8] and also by Shneerson and Leibush,[20] to have virtually no effect. The diethanolamine used was stated by the manufacturers to be of 95 to 97% purity, the impurities being mainly water, together with small proportions of mono and tri-ethanolamine. No attempt was made to purify the amine.

The experimental results are presented here as K_G, the overall mass-transfer coefficient, calculated by dividing the weight of carbon dioxide absorbed per hour by the interfacial area and the mean partial-pressure of carbon dioxide in the column. In a small number of experiments at high degrees of conversion, allowance had to be made for the back pressure of carbon dioxide from the solution. Figs. 4 and 5 show K_G plotted against Γ, the liquor rate per unit of wetted perimeter, the parameter being the percentage conversion of the amine to its carbonates. This function was calculated employing the arbitrary definition given by Cryder and Maloney.[8] These authors defined 100% conversion as complete conversion of the amine to the amine carbonate and 200% as complete conversion to the amine bicarbonate. Fig. 6 shows K_G as a function of this latter variable. Fig. 7 shows K_G as a function of the gas strength and Fig. 8 shows K_G as a function of the normality of the amine solution.

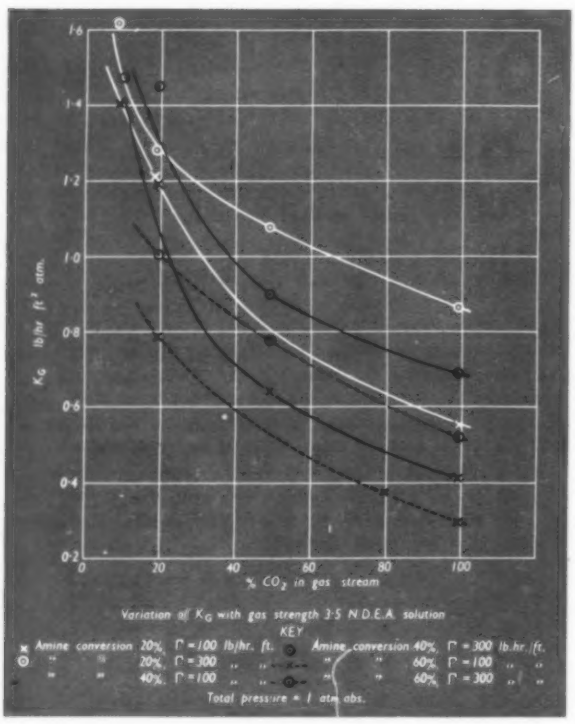


Fig. 7. Overall coefficient against CO_2 concentration in gas stream.

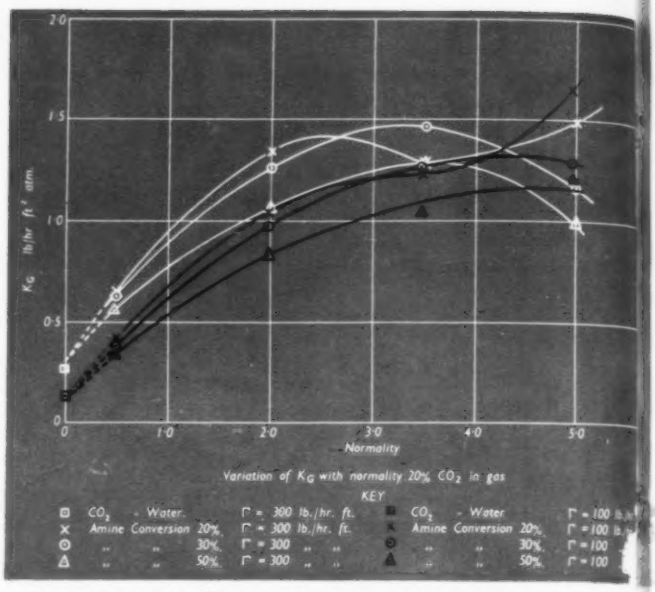


Fig. 8. Overall coefficient against amine concentration.

It was noticed, during the course of the experimental work, that the regeneration process by which the carbon dioxide was expelled from solution resulted in a lowering of the absorption capacity of the solution. The reason for this is obscure, but a likely cause is loss of amine through thermal decomposition. Dixon[9] and Chambers and Wall,[7] working with monoethanolamine in centrifugal absorbers, experienced similar troubles after regeneration of the absorbent, and noticed that the fall in absorptive power was accompanied by an increase in viscosity. Viscosity determinations made during the course of the work reported here generally confirmed this. Chambers and Wall[7] also stated that it was necessary to redistil their monoethanolamine absorbent in an all-glass vacuum still occasionally to maintain its efficiency. It seems, therefore, that regeneration under partial vacuum would prevent the deterioration of the absorbent as the temperature required would not be so high. The drop in absorptive power amounted to as much as 20% in some cases after several regenerations of the amine solution. The use of nitrogen as the purge gas in the stripping column instead of air had no apparent effect on the deterioration of the solution.

A further point of interest noticed during the work was the disappearance of ripples from the discs in the absorption column at a certain flow rate for the solution of high normality. Calculation of the Reynolds number for the flow rate at which rippling first appeared gave a value in good agreement with the value calculated from the equations given by Grimley[11]:

$$\frac{S^3\rho}{\mu^4 g} = 0.3\,(Re)^8 \qquad \ldots . (6)$$

This is rather surprising, in view of the fact that Grimley's equation was obtained from experiments with liquids running down smooth surfaces.

To be concluded

THE DESIGN OF BUBBLE-CAP PLATE COLUMNS

Some simple methods are outlined for calculating the variables of bubble-cap plates to assist in the design of the plates for any given problem

by T. V. MOLESWORTH, B.Sc. (Tech.), A.M.I.Chem.E.*

SUFFICIENT information is now available to enable the design of bubble-cap plates, excellent components for producing good interfacial contact between two fluid-phases, to be calculated much more accurately than hitherto. Some of the factors to be considered in designing the plates, including provision of sufficient capacity for liquid and vapour; vapour and liquid velocities; pressure drop; plate efficiency, stability and layout; and cap design are discussed below.

Handling Capacity

Vapour rate

Liquid and vapour rates are interdependent to some extent. The efficiency of a bubble-cap plate, as with any contactor, depends on the efficiency of contact between liquid and vapour. This, in turn, depends largely on the agitation caused by the vapour bubbling through the liquid. At a low vapour velocity a low efficiency is obtained because of:

(*a*) a decreased level on the plates;
(*b*) channelling of vapour due to slight variations in liquid head;
(*c*) large vapour bubble formation.

As the vapour velocity is increased, the plate efficiency increases until increasing entrainment of the liquid begins to reduce efficiency once more. In addition, too high a vapour velocity tends to "cone" liquid away from the bubble-cap slots. Maximum plate efficiency occurs in practice over a range of vapour velocities. A good general design guide may be attained from the equation:

$$G = C\sqrt{\rho_V(\rho_L - \rho_V)} \qquad \ldots . (1)$$

where G = lb./hr/ft^2 vapour in empty column
ρ_V = vapour density (lb./ft^3)
ρ_L = liquid density (lb./ft^3)
C = a parameter depending on plate spacing and surface tension of liquid.

The values of C may be obtained from Fig. 1.

This equation is based on Newton's law for the terminal velocity of liquid droplets in gas.[1] The vapour velocity may be up to twice the figure calculated without any serious decrease in efficiency. A study of actual figures will show that the above equation gives rather conservative results. The superficial vapour velocity in the empty column should be in line with the slot vapour velocity u_s, and for pressures $\geqslant$ 1 atmosphere the vapour velocity through riser and slots should be 9-14 ft/sec. For vacuum work it is more important to design for minimum pressure-drop, and it is necessary to limit the vapour velocity to this end. For increased plate spacing or decreased depth of liquid on the plate, the vapour velocity may be increased.

Another method of expressing vapour flow is with the function F_s, which is given by the following equation:

$$F_s = u_s\sqrt{\rho_V} \qquad \ldots . (2)$$

where u_s = slot velocity, ft/sec.

It is common practice to design plates with vapour rates corresponding to $F_s = 11$, especially if handling large quantities of liquid. At F_s equals 12.5 to 13, the vapour will "cone" liquid away from the caps, resulting in poor interphase contact.[2]

Liquid rate

To a large extent the maximum liquid rate is determined by the requirements of plate stability and pressure-drop, which are dealt with later. It is also very important to avoid flooding the column. If the liquid rate is increased beyond normal, the downcomers eventually become full and any further increase causes a build-up of liquid on the plates until the column is flooded. This effect is more serious with liquids which tend to foam. The method of calculating the liquid level in the downcomers is given below, but it can be said generally that ample downcomer capacity should always be provided. A reasonable liquid velocity in the downcomers is 2 in. to 4 in. per second, but it is well to over-design on this. It is important to ensure that there is a quieting area between the last row of caps and the downcomer weir to allow good disengagement of vapour from the liquid. This may be done by providing either plenty of space, or some kind of baffling. Residence time required in the quieting zone is at least 1 second per foot depth of liquor. Pyott, Jackson and Huntington[3] give a useful account of the effect of liquid rate on various properties of a bubble-cap column.

Height of Liquid in Downcomers

Fig. 2 shows how the liquid levels exist on a bubble-cap plate. The value of H may be calculated by the use of Equation (3), which has been derived from the various resistances to flow of fluid through the system:

$$H = 2(h_w + h_{cr} + \triangle h) - h_{sp} + 0.06v_{max}^2 + 0.085u_{max}^2\left(\frac{\rho_V}{\rho_L}\right) \qquad \ldots . (3)$$

where v_{max} = maximum liquid velocity in or under the downcomer, determined at the narrowest constriction (ft/sec.); and
u_{max} = maximum vapour velocity through the riser, cap or slot (ft/sec.).

h_{cr} and $\triangle h$ may be calculated by the methods given below.

In small-diameter columns $\triangle h$ is negligible for any given liquid rate. A long, high weir is preferable to a low, short one, since the former gives less variation in liquid level. For chord-type weirs, the calculations are more complex.[4] It is clear that, to avoid flooding, H must be

* Development Manager, Q.V.F. Ltd.

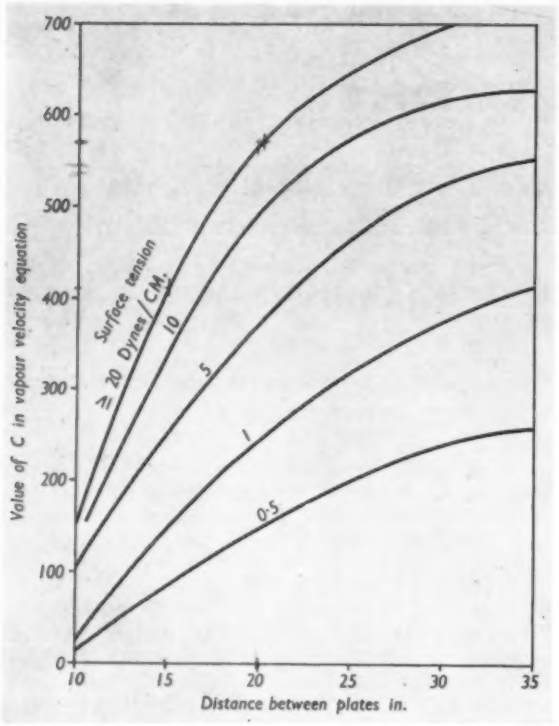


Fig. 1.

less than H_{max}. It is important to note that frothy or foamy liquids give an apparent increase in H, and therefore tend to cause flooding of the downcomers.

Calculation of h_{cr} and $\triangle h$

If D is the weir diameter, assuming a circular weir, and $D > 4h$, then the Francis weir formula, modified, applies:

$$Q = 0.0067\ W\ (0.6h_{cr})^{1.5} \quad \ldots . (4)$$

where Q = liquid flow (ft³/sec.).
W = weir length (in.).
h_{cr} = crest height (in.).

If the weir is circular and near to the edge of the plate, then only about $\frac{1}{2}$ in. to $\frac{3}{4}$ in. of the total length is effectively available.[5]

Normally a bubble-cap plate should only be used where the condition $D > 4h_{cr}$ applies, since the liquid overshoots the crest by a distance o_s, which approximately equals 2 h_{cr}. To avoid flooding, D should be greater than $2o_s$ and hence greater than $4h_{cr}$. If, by any chance, D is less than $4h_{cr}$, then more complex formulæ are required. If $4h_{cr} > D > 2h_{cr}$ then:

$$Q = 0.00823\ D^{1.675}\ h_{cr}{}^{0.825} \text{ (Refs. 6, 7)} \quad \ldots . (4a)$$

If $D < 2h_{cr}$, then $Q = 0.0065\ D^2\ h_{cr}{}^{0.5}$ . . . . (4b)

On any plate there is a hydraulic gradient, $\triangle h$, which provides the driving force to move the liquid across the plate, against the resistance of bubble caps, plate-support rods, other accessories, and also the vapour rising from the slots. This concept is not universally accepted, and at least one worker considers that the driving force is provided by the energy of the rising bubbles. However, it will be assumed for the present purpose to be correct. Calculation of $\triangle h$ is very difficult, and empirical equations only can be offered for its estimation. Most of the results correlated were for essentially standard caps and plate layouts, and the relation should be used with caution for different arrangements. Klein[8] indicated that, with no vapour flow, there is no effective hydraulic gradient, even at liquid rates greater than those normally employed. He concluded that the loss in head is due to high frictional losses for the flow of the vapour-liquid mixture. Work on the flow of two-phase mixtures in pipes tends to support this view.

The following equation may be used to calculate $\triangle h$:

$$\frac{\triangle h}{12} = \frac{f'\ v_f{}^2\ B}{g\ r_h} \quad \ldots . (5)$$

which gives $\triangle h$ in feet loss of head from inlet to outlet calming sections.

f' = friction factor

v_f = liquid velocity in foam (ft./sec.) = $\dfrac{Q_w}{\rho_f\ L_\circ\ b}$ . . . . (5a)

Q_w = liquid rate (lb./sec.)

ρ_f = foam density (lb./ft.³) = $\dfrac{\rho_L}{3}$ by assumption

$L_\circ$ = foam height (ft.) = $2h_\circ$ by assumption
b = plate width (ft.)
B = length of bubbling section (ft.)
g = 32.2 ft./sec.²

r_h = mean hydraulic radius (ft.) = $\left(\dfrac{b\ L_\circ}{b + 2\ L_\circ}\right)$ . . . . (5b)

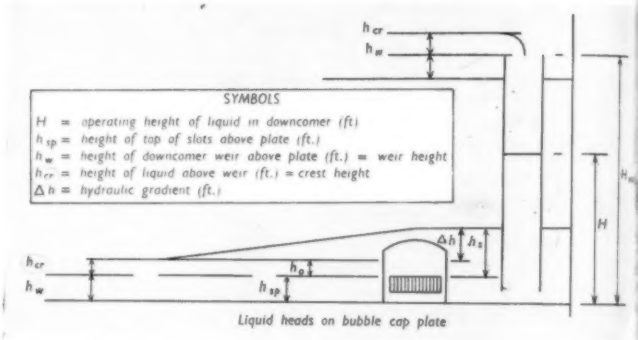

SYMBOLS
H = operating height of liquid in downcomer (ft)
h_sp = height of top of slots above plate (ft.)
h_w = height of downcomer weir above plate (ft.) = weir height
h_cr = height of liquid above weir (ft.) = crest height
△h = hydraulic gradient (ft.)
Liquid heads on bubble cap plate

Fig. 2.

Values of f' were correlated as a function of a modified Reynold's number Re', which equals $\dfrac{r_h\ v_f\ \rho_f}{\eta_f}$ where η_f = viscosity of foam = $\left(\dfrac{\eta_L}{3}\right)$ by assumption.

This correlation is given in Fig. 3, and to use this it is necessary to know $h_\circ$.

$$h_\circ = h_w + h_{cr} - h_{sp} \text{ all in feet.} \quad \ldots . (5c)$$

$h_\circ$ is the hydrostatic head in the outlet calming section, and is probably the most important single factor which determines $\triangle h$.

η_L is the liquid viscosity, and it is not generally agreed that it has any effect. It is recommended that for values of η_L up to and including 0.000672 lb/ft sec. a value of 0.000672 be used. For higher viscosities, the actual value should be used.

If the value of $\triangle h$ is known for a particular plate and operating conditions, then the following may be used to assess the change in $\triangle h$, produced by a change of one or other of the variables:

(1) $\triangle h$ may be either increased or decreased by an increase in F_s.
(2) $\triangle h$ is increased by an increase in liquid rate, or the number of rows of caps in the line of liquid flow.

(3) $\triangle h$ is decreased by an increase in h_0, skirt clearance or cap spacing.

Efficiency

In the design of bubble-cap plate columns it is necessary to determine the number of plates required in the column. The number of theoretical plates may be obtained by a number of well-known methods, and this value must be divided by the plate efficiency to determine the number of actual plates.

Plate efficiency may be expressed in several ways. Overall plate efficiency is the ratio of the number of theoretical plates to the number of actual plates. Murphree plate efficiency E_{mv} expresses the efficiency for a single plate as follows:

$$E_{mv} = \frac{Y'_i - Y'_o}{Y'_i - Y'^*} \quad \ldots . (6)$$

where Y'_i = mol fraction of more volatile component in the vapour phase of the total vapour entering the plate.

Y'_o = mol fraction of more volatile component in the vapour phase of the total vapour leaving the plate.

Y'^* = mol fraction of more volatile component in the vapour phase in equilibrium with the liquid leaving the plate.

The Murphree plate efficiency assumes that the liquid on each plate is completely mixed, and that all the vapour comes in contact with liquid of the same composition as that leaving the plate. The assumption is not correct, because there is incomplete mixing of the liquid as it flows across the plate. In addition, the vapour that passes through the caps near the inlet downcomer comes into contact with a liquid richer in the more volatile components than the liquid leaving the plate. In this case, the Murphree efficiency would be greater than 100%.

Point efficiency is the efficiency at a single point on the plate. In this paper, plate efficiency will mean overall efficiency, unless a different definition is specified. Plate efficiency, generally speaking, is insensitive to minor variations in plate layout, if ample fluid-handling capacity is provided. The overall plate efficiency is generally adequate as a basis for calculating the number of actual plates required in a column. Overall efficiency depends mainly on the properties of the materials being handled. Viscosity is regarded as the most important single property, although not all workers are in agreement about this. Some actual figures show the efficiency ranges which may be expected:

Moderate-diameter columns, volatile hydrocarbons such as gasoline 100%
Low-pressure, hydrocarbon absorbers ..... 20 to 45%
High-pressure, hydrocarbon absorbers ..... 45 to 65%
Alcohol-water system ..... 70 to 100%

Various attempts have been made to predict plate efficiencies. Bakowski[9] has proposed the following equation:

$$log\left(\frac{1}{1-E_{mv}}\right) = c\,S^4\sqrt{\frac{T^2}{M^2\,u_s\,P}} \quad \ldots . (7)$$

where E_{mv} = Murphree efficiency
S = slot submergence
T = absolute temperature
M = molecular weight
u_s = slot vapour velocity
P = absolute pressure
c = constant.

Good agreement is obtained between predicted and observed values. Chu[10] has derived a different equation for both distillation columns and absorbers.

For distillation columns:

$$E_o = 54.1\ (10)^{-0.06 + 0.092\,h_e\left(\frac{L}{V}\right)0.295\ (\eta_L L.\alpha)^{-0.246}\ \text{feed}} \quad \ldots . (8)$$

limits: $\frac{L}{V}$ from 0.4 to 8, h_e not exceeding 1.5 in.

For absorbers:

$$E_o = 45.6\ (10)^{-0.06 + 0.92\,h_e\left(\frac{L}{V}\right)0.245\left(\frac{H\,P}{\eta_L}\right)0.380\ \text{feed}} \quad \ldots . (8a)$$

limits, as for distillation columns.

Symbols:
E_o = overall efficiency
h_e = effective submergence = $h_L + \frac{1}{2}h_s$ in., (the effect of variable slot opening is considered negligible)
α = relative volatility of the key components
η_L = viscosity of liquid (feed) lb/hr ft in Equation (8) centipoises in Equation (8a)
H = Henry's law gas constant, lb. mol./ft³ atmos.
P = pressure (atmospheres)

Various empirical formulæ are also available for the estimation of efficiency:

The first equation applies to petroleum and similar hydrocarbon mixtures.

$$E = 18\text{—}60\ \log\ \eta_m \quad \ldots . (9)$$

where η_m=molal average viscosity of feed at the average column temperature in centipoises for each component at the arithmetic mean temperature at the top and bottom of the column. It applies for viscosities from 0.07 to 1.4 centipoises.

The second equation is more widely applicable to a range of mixtures including acetic acid-water, beer, and ethanol-water. It is given in the form of a plot in Fig. 4—a correlation between approximate plate efficiency and relative volatility of the two key components.

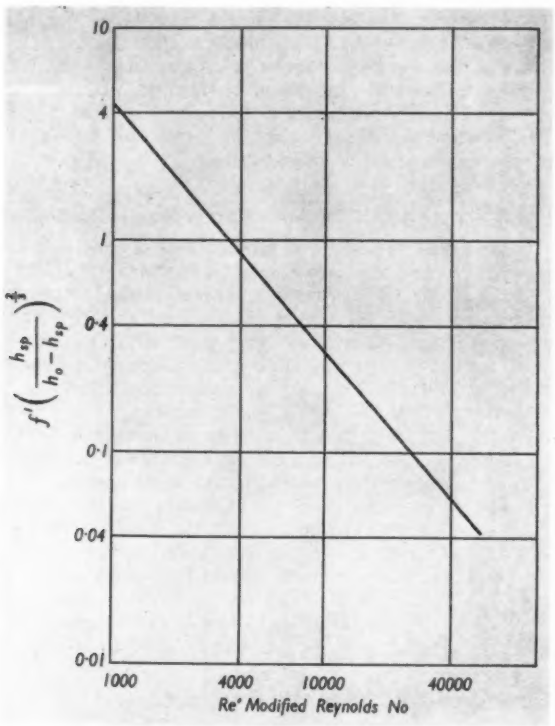


Fig. 3.

Overall relative volatility $= \alpha_{av} =$

$$\frac{y/x \text{ for more volatile component}}{y/x \text{ for less volatile component}}$$

at the arithmetic mean temperature and pressure at the top and bottom of the column. Both the above relations must be used with caution.

Pressure Drop

Pressure drop is, of course, of considerable importance when considering the operation of the column as a complete unit, especially for vacuum work. By pressure drop may be meant: (1) ΔP_o the pressure drop at "zero seal", i.e., with the liquid at the top of the slots, no flow taking place either of liquid or vapour; (2) ΔP the pressure drop under normal operating conditions (a value of greater practical importance).

Methods of calculating ΔP_o are given in Appendix 1. ΔP may be obtained from:

$$\Delta P = \Delta P_o + \text{height of liquid above slots} \quad \ldots . (10)$$

or from:

$$\Delta P = \text{liquid head above slots} + \frac{\text{actual slot opening}}{2} \text{ under working conditions.} \quad \ldots . (10a)$$

The actual slot opening may be calculated from the method given by Cross and Ryder.[11] This is summarised in Appendix 2.

Cailley and colleagues[12] describe an investigation into the pressure drop through a bubble-cap plate, and a clearer picture of the various factors involved may be obtained from this.

Plate Stability

Plate stability is a factor only likely to be encountered on large-diameter plates (say, over 2 ft in diameter). It has already been shown that there exists on any plate a hydraulic gradient Δh. If this gradient is too high, then more vapour can issue from the caps at low liquid level than from those at high liquid level. In extreme cases, the pressure drop across the plate at the "deep end" may be insufficient to prevent liquid flowing back down the risers. A plate is said to be unstable if no vapour issues from some of the caps. This is an arbitrary definition, since a "stable" plate is not necessarily well balanced and efficient. Most of the vapour flow may be at one side, giving increased entrainment at that point. The ideal is a stable plate, with a minimum hydraulic gradient.

It can be shown that, for stability, the following expression must be satisfied:

$$\Delta P_o \geqslant \Delta h + 0.3\, h_o \quad , \quad \ldots . (11)$$

where h_o is the minimum slot submergence.

Fig. 5 shows the flow system on a typical plate. For balance, $\Delta P = P_1 - P_2$, and also $\Delta P = \Delta P_U = \Delta P_D$. At point U bubbling is so slight that negligible vapour issues from the slots, and resistance to vapour flow is due to hydraulic head above the slots. This resistance may be divided into two components such that

$$\Delta P_U = h_o + \Delta h.$$

At point D, resistance is due to frictional losses and hydraulic head, so that:

$$\Delta P_D = \Delta P_o + h_o$$

Thus: $\Delta P_o + h_o = \Delta h + h_o$

The effect of h_o may be assumed to be equal at both sides of the plate, and therefore at the point of bare stability: $\Delta P_o = \Delta h$

If $\Delta P_o > \Delta h$ the plate is stable and vice versa. If Δh is so large that the hydrostatic head above the top of the cap riser at point U exceeds ΔP_o, liquid will actually flow down the riser.

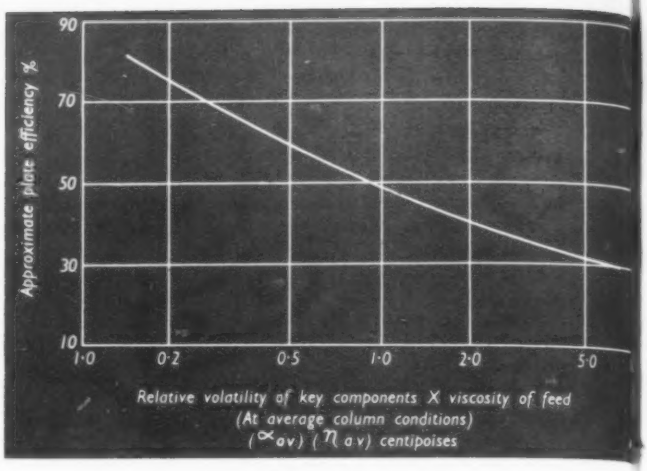


Fig. 4.

The above calculation is not, in fact, quite accurate. Actually, the liquid on the plate is aerated by the upflowing vapour at the side near the downcomer, point D, and offers less resistance than is indicated by its depth. At the opposite side, point U, virtually no vapour is rising, and the liquid is unaerated. Hence the equation for plate stability becomes: .

$$\Delta P_o + \psi h_o \geqslant \Delta h + h_o \text{ or}$$

$\Delta P_o \geqslant \Delta h + h_o\,(1 - \psi)$, where ψ is the aeration factor $\frac{P_1 - P_2}{S_2 - S_1}$, or the increase in pressure drop across the plate per unit increase in depth of clear liquid above the top of the slots. ψ, which is dimensionless, is a function of vapour rate and seal depth, and is usually about 0.7. Therefore, ΔP_o must exceed Δh by about 0.3 h_o for stability, hence Equation (11). Since deep seals are usually employed when handling high liquid-rates, $(1 - \psi)\, h_o$ may sometimes affect stability, as much as Δh.

In all the equations above, consistent units must be employed. When designing a plate from the point of view of stability, it is not unusual to make slot area 5% of the column superficial area, in order to satisfy the conditions for stability indicated.

Entrainment

Entrainment should be at a minimum—a condition that may be attained by using wide plate-spacings, large downcomers, and mist extractors between plates.[3] However, over-much emphasis is probably laid on entrainment. It has been found, for example, that up to 10% mol entrainment does not materially affect plate efficiency. From the practical viewpoint, entrainment has more effect if the feed-plate is near the top of the column.[13] A few experimental figures may be of use. At a superficial vapour velocity u of 6 ft/sec., high efficiencies were obtained.[14] At $u > 2$ft/sec., entrainment was found to be approximately inversely proportional to slot area, but below 2 ft/sec. slot area had little effect, probably because less than the total available slot area was used.[13] It has also been found that efficiency was more or less constant for values of u from 0.2 to 2.5 ft/sec., but insufficient data were available at $u > 2.5$ ft/sec.[15] If the other factors in column design are carefully planned, entrainment is not likely to be serious.

Cap Design and Plate Layout

Bubble caps and plates may be of any size or shape, but, in general, the following is a reliable guide to design and

layout. Riser, annulus and slot area of a single cap should be about equal to one another to obtain minimum pressure drop. This is particularly important for vacuum work. Circular caps are generally better than tunnel caps. Small-diameter caps give more slot area, and more free space for liquid flow, than large caps. The slot area is generally 10% to 20% of the column superficial area (but see section above on plate stability). Caps are generally arranged on triangular centres to give the liquid a staggered path across the plate and, hence, good contacting. It is important to avoid short-circuiting of the liquid, and baffles may be used if necessary. The spacing between the caps should give ample turbulence to the liquid, but should not be so small as to produce spouting or jetting. Spacing of 1 in. to 3 in. is reasonable. A recommended spacing formula is:

$$\text{Spacing in inches} = 0.5 + 0.25\,D \qquad \ldots . (12)$$

where D is cap diameter in inches.[5]

A space of 1 in. to 2 in between the caps and the column wall and of 2 in to 3 in. between caps and weirs is usually considered adequate. It is sometimes desirable to blank off the slots nearest to the downcomer weir.

Total submergence of the caps is advantageous because it improves liquid distribution. There is less resistance and hence a smaller hydraulic gradient. Also the space above the caps should be as free as possible to allow free passage of liquid, and any attachments should be placed to allow a flow as near streamline as possible. Some skirt clearance is desirable, because this reduces the hydraulic gradient most effectively. Yet it introduces the possibility of part of the liquid crossing the plate without intimate contact with the vapour; such a condition would be especially serious if the column were operated at reduced capacity. As to slots, narrow ones with ample submergence give the best results.

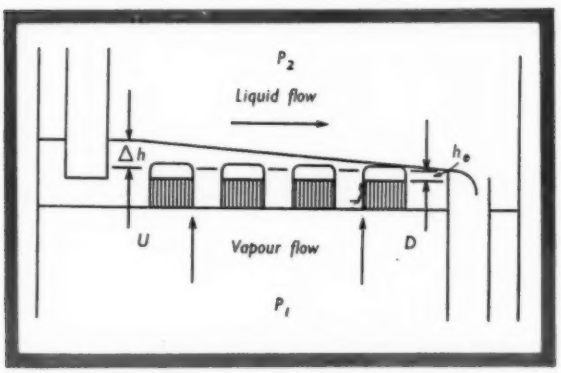


Fig. 5.

Plate Spacing

The spacing of plates depends both on the entrainment produced, and on the pressure drop across the plate, and hence (perhaps most importantly) on the height of liquid in the downcomers. Two relations may be used as a guide to plate spacing:

(*a*) plate spacing in feet = u ft/sec. . . . . (13)

(*b*) plate spacing = $2H$ . . . . (13a)

The Expression (13a) gives good overload-capacity for foamy liquids and, in general, makes for good practice. Increase of spacing will decrease entrainment, but will increase the height, and therefore the cost of the column. A plot of efficiency versus vapour velocity shows that it is rather more economical to build a small-diameter high column than a squat one of large diameter.

Appendix 1

Calculation of $\triangle P_o$

$\triangle P_o$ may be divided up into two components h_c and h_s, such that:

$$\triangle P_o = h_c + h_s \qquad \ldots . (14)$$

where h_c = pressure drop through riser and cap in liquid.

h_s = pressure drop in flowing through slots in liquid.

h_c is chiefly a kinetic velocity effect, due to changing cross-sectional areas. An empirical equation has been developed as follows[6]:

$$h_c = 1.1\,u_r^2\,\frac{\rho_V}{\rho_L} \qquad \ldots . (14a)$$

where u_r = maximum vapour velocity in the riser or cap ft/sec.

The estimation of h_s is not so easy. If $h_s \leqslant$ slot height h_{sl}:

$$h_s = 0.12\,\frac{\gamma}{\rho_L} + K\left(h_{sl}\,u^*_s\,\sqrt{\frac{\rho_V}{\rho_L - \rho_V}}\right)^{0.67} \qquad \ldots . (14b)$$

where γ = surface tension of liquid dynes/cm

$$K = \text{empirical constant} = 1 - \left(\frac{u_r}{2\,u^*_s}\right)^2$$

u^*_s = slot vapour velocity based on total slot area ft/sec. For general use K may be taken as equal to 0.72.

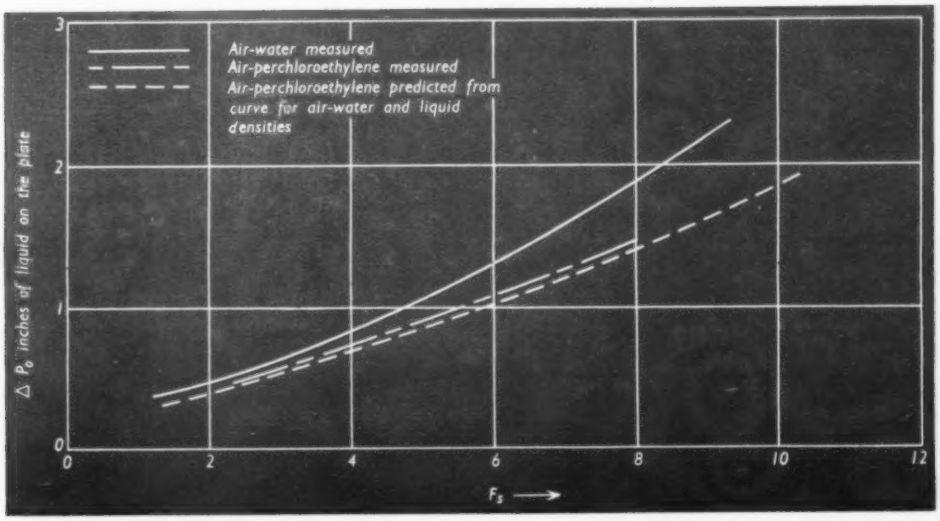


Fig. 6 (Right).

If $h_s > h_{sl}$ a correction must be made. At the point where the slots are just wide open, the value of h_s as obtained by Equation (14b) becomes equal to h^*_s. The corresponding slot vapour velocity u^*_s should be calculated from Equation (14b), using a value of $h^*_s = \frac{1}{2}h_{sl}$. The true value of h_s may then be calculated from:

$$h_s = h^*_s \left(\frac{u_s}{u^*_s}\right)^2 \quad \ldots . (14c)$$

where u_s = true slot vapour velocity, ft/sec.

The values of $\triangle P_o$ obtained by calculation are supported by the results of experimental work. Fig. 6 is a plot of $\triangle P_o$ against F_s for the systems air-water, and air-perchloroethylene. The data were obtained using 4 in. diameter caps with 50 slots per cap, each slot being 1 in. $\times \frac{1}{8}$ in., at zero skirt clearance.[2]

Appendix 2

Calculation of actual slot opening
(Cross and Ryder[11])

For rectangular slots

$$h = \alpha \text{ for } \left(\frac{\alpha}{\beta}\right)^2 > V > 0 \quad \ldots . (15)$$

$$h = \beta V^2 \text{ for } V > \left(\frac{\alpha}{\beta}\right)^{\frac{1}{2}} \quad \ldots . (15a)$$

where:

$$\alpha = \frac{T}{W g \rho_L} + \sqrt{\left(\frac{T^2}{W^2 g^2 \rho_L^2} + \frac{2T}{g \rho_L}\right)} \ldots . (15b)$$

and $\beta = \left(\frac{2.60}{W}\sqrt{\frac{R}{2g}}\right)^{\frac{2}{3}} \quad \ldots . (15c)$

For triangular slots

$$h = \alpha \text{ for } \left(\frac{\alpha}{\beta}\right)^2 > V > 0 \quad \ldots . (16)$$

$$h = \beta . V^2 \text{ for } V > \left(\frac{\alpha}{\beta}\right)^{\frac{1}{2}} \quad \ldots . (16a)$$

where:

$$\alpha = \sqrt{\frac{2T}{g \rho_L}\left(\frac{2A}{B} + 1\right)} \quad \ldots . (16b)$$

$$\beta = \left(6.62 \frac{A}{B}\sqrt{\frac{R}{2g}}\right)^2 \quad \ldots . (16c)$$

Symbols

h = slot opening (ft)
T = surface tension of liquid, poundals/ft (1 dyne/cm. $\equiv 2.2046 \times 10^{-3}$ poundals/ft)
W = rectangular slot width (ft)
A = height of triangular slot (ft)
B = base width of triangular slot (ft)
V = gas flow rate (ft^3/sec.)

$$R = \frac{\rho_v}{\rho_L - \rho_v}$$

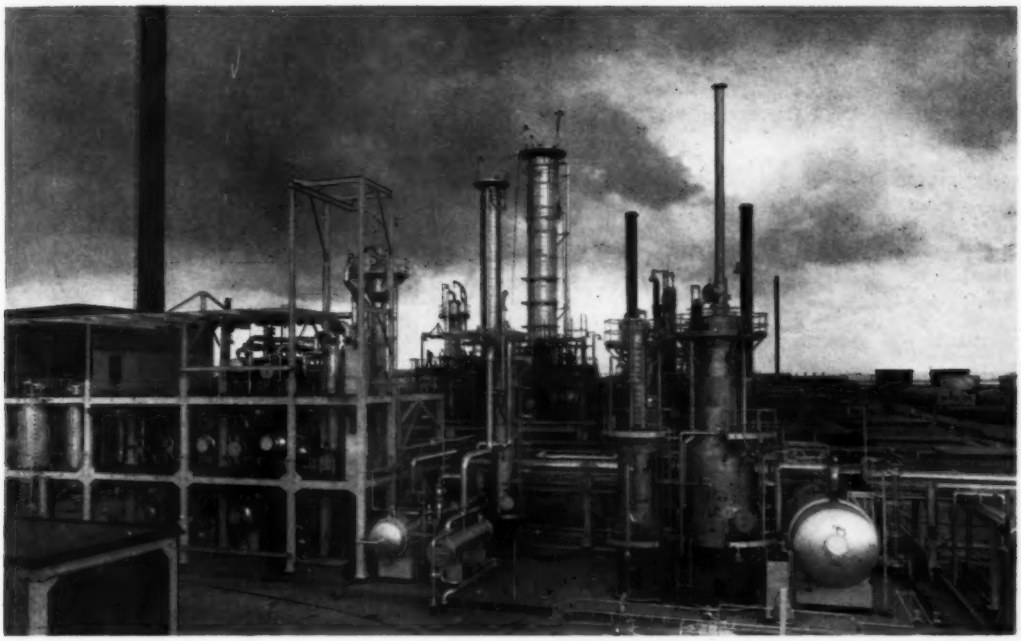
REFERENCES
[1] Souders and Brown: *Ind. Eng. Chem.*, 1934, **26**, 98.
[2] Kemp and Pyle: *Chem. Eng. Prog.*, 1949, **45**, 435.
[3] Pyott, Jackson and Huntington: *Ind. Eng. Chem.*, 1935, **27**, 821.
[4] Brown *et al.*: "Unit Operations," Chapman & Hall, London, 1950, pp. 352-53.
[5] Freshwater, D. C.: private communication.
[6] Robinson and Gilliland: "Elements of Fractional Distillation," McGraw-Hill, London, 1950, p. 403.
[7] Brown: *Trans. Am. Inst. Chem. Eng.*, 1936, **32**, 321.
[8] Klein: D.Sc. thesis in chem. eng. M.I.T., 1950.
[9] Bakowski: *Chem. Eng. Sci.*, 1952, **1**, 266.
[10] Chu *et al.*: *J. Appl. Chem.*, 1951, **1**, 529.
[11] Cross and Ryder: *J. Appl. Chem.*, 1952, **2**, 51.
[12] Cailley *et al*: *Chem. Eng. Prog.*, 1953, **49**, 553.
[13] Sherwood and Jenny: *Ind. Eng. Chem.*, 1935, **27**, 265.
[14] Lewis: *Ind. Eng. Chem.*, 1936, **28**, 399.
[15] Peavy and Baker: *Ind. Eng. Chem.*, 1937, **29**, 1056.
[16] Drickamer and Bradford: *Trans. Am. Inst. Chem. Eng.*, 1943, **39**, 319.
[17] Brown and Lockhart: *Trans Am. Inst. Chem. Eng.*, 1943, **39**, 63.
[18] Geddes: *Trans. Am. Inst. Chem. Eng.*, 1946, **42**, 79.
[19] Smith and Kelm: *Chem. Eng.*, 1951, **58**, 155.
References not mentioned in the text include:
[20] Perry: "Chemical Engineer's Handbook," third edition, McGraw-Hill, p. 396.
[21] Good, Hutchinson and Rousseau: *Ind. Eng. Chem.*, 1942, **34**, 1445.
[22] Othmer: *Ind. Eng. Chem.*, 1930, **22**, 322.
[23] Davies: *Ind. Eng. Chem.*, 1947, **39**, 774.
[24] Jones: *Chem. and Proc. Eng.*, 1955, **36**, 291.
[25] Atkins: *Chem. Eng. Prog.*, 1954, **50**, 116.

The author wishes to thank Dr. D. C. Freshwater for helpful criticism during the preparation of this paper.

TABLE 1. Working Data on Bubble-Cap Plates

System	Pressure p s i g	Slot height (in.)	Total slot area/plate ($in.^2$)	† Static seal (in.)	* Submergence (in.)	Column diameter (in.)	Superficial vapour velocity (ft/sec)	Minimum slot vapour velocity (ft/sec)	Liquid downflow (ft^3/hr)	Liquid velocity in downcomer (ft/sec)	Downcomer area ($in.^2$)	Remarks	Plate spacing (in.)
Air/Kerosene	14·7	1	12	1¼	1	12·5	1·049	10·75	66·9	0·472	5·65		—
Paraffin Hc's	332	1	—	1	>1	72	—	—	3485	0·761	183·2 min		24 and 30
Paraffin Hc's	250	1¼	446·4	½(?)	1	72	0·559	5·1	8700	0·95	366 min		30
Ethanol/Water	14·7	½	0·557	½	0·684	6	0·218	11·1	0·1524	—	—		—
Benzene/Carbon-tetra-chloride	14·7	½	1·75	1¼	>1¼	6	0·512	33·2	1·179	0·24	0·1965	Corning 6-in. plate	8¼
Toluene-methyl-cyclo-hexane	14·7	½	1·75	1¼	>1¼	6	0·521	34·8	1·254	0·255	0·1965	Corning 6-in. plate	8¼
Based on ethanol	—	~1	~24·5	¼-½	>¼-½	23·5	2·24 assumed	39·7	—	—	~1·23	Corning 24-in plate	10½
Based on ethanol	—	½	13·5	1	>1	12	2·24 assumed	18·7	—	—	0·888	Lough-borough 12-in plate	12

†Static Seal = Height from top of slots to top of downcomer weir. *Submergence = Mean height from top of slots to liquid surface.
The figures, from which the above table was compiled, were obtained from References 3, 16, 17, 18, and 19, and manufacturers' publications.
The data for the Corning 24-in. plate are taken from Corning drawing 10360-351 Rev 4 and are approximate.



A BRITISH DODECYL-BENZENE PLANT

A £1,600,000 plant erected by the Shell Chemical Co. at Shell Haven, Essex, for the production of dodecyl benzene by the HF process is now in full production. It has an annual capacity of about 30,000 tons of the alkylate, and it commenced operation in July. Built on the west site at Shell Haven, where use can be made of services installed centrally for installations that are part of Shell's post-war development programme, the plant has been designed by B.P.M. (Royal Dutch/Shell Group) and was based on experience gained in the Netherlands. It covers about 8 acres of ground, and was constructed by Foster Wheeler Ltd., London.

The essential reaction, a combination of a suitable olefine (propylene tetramer) with benzene in the presence of an acidic catalyst, is simple. However, special precautions are taken, the company states, to ensure high quality of the product, which, as sold, is a bright colourless liquid. The conversion of benzene to dodecyl benzene is effected by vigorously mixing the olefine and benzene with the catalyst in a reaction tank. To minimise the production of by-products, careful adjustment is maintained of the reaction conditions, including temperature, residence time, ratio of benzene to olefines and amount of catalyst. Also, a high purity of feed stock is insisted upon, and the fulfilment of this requirement is helped by the fact that all of the olefine and much of the benzene is manufactured by the parent organisation. The benzene is practically free from toluene and has a freezing point of 6°C—a property which may cause difficulty during the winter. After the reaction stage the acid catalyst is first removed. Most of it can be separated after settling. The supernatant layer is then distilled under vacuum to remove unconverted benzene and traces of the catalyst, and to decompose compounds formed between benzene and the acid. A series of three treaters removes further traces of catalyst and organic impurities, and then the crude dodecyl benzene is distilled under high vacuum (about 10 mm. at the top of the column and 100 mm. at the bottom), the lighter impurities being removed at the top, the heavier at the bottom, and the pure dodecyl benzene free from water being drawn off at a draught tray.

To maintain the catalyst at the necessary state of purity, a constant proportion of it is removed in a slip stream, and is subjected to chemical treatment. The neutral tar obtained from the distillation columns is used as a fuel. Heating throughout the plant is by a hot-oil circulation system. The whole process is controlled from a central control room in which throughput temperatures, *pH* of effluents and cooling waters, and other variables are under supervision. A system of alarms is also provided in the room giving warning, for example, of excessive *pH* or of the emergency use of showers by operatives who are working in the acid-handling area. In extreme emergency the whole plant can be shut-down instantly from the control panel, the contents of the reactor vessel being dumped into a tank, and the reactor flooded with nitrogen. Because of the high degree of automatic control, fewer than a dozen operatives are required on the plant per shift.

The layout of the plant follows logically from the sequences of the process steps. The various sections of the plant—tank farm, pump house, reaction section and distillation section—are placed in rectangular plots parallel to each other. In addition to the control room already mentioned, the buildings associated with the plant include offices for the supervisory staff and a small laboratory.

The product is exported from the site in road or rail tankers, or it may be piped through a three-mile pipe-line to jetties on the Thames Estuary for transport by ship. To guard against contamination of the final product, the pipe-line is used solely for the dodecyl benzene. Part of the alkylate produced at the plant is carried to Stanlow, Cheshire, to be converted to detergents by sulphonation within the Shell organisation. It is expected that, in 1957, 13,000 tons will be exported overseas.

PLASTICS CAN SOLVE YOUR EQUIPMENT FABRICATION PROBLEMS

Many plant items can be constructed from plastic materials on site with comparative ease, and the spread of this practice throughout the chemical industry is accelerated because of the slow deliveries of certain types of equipment. The trend in chemical works is for the plastics technician to become as important as the plumber.

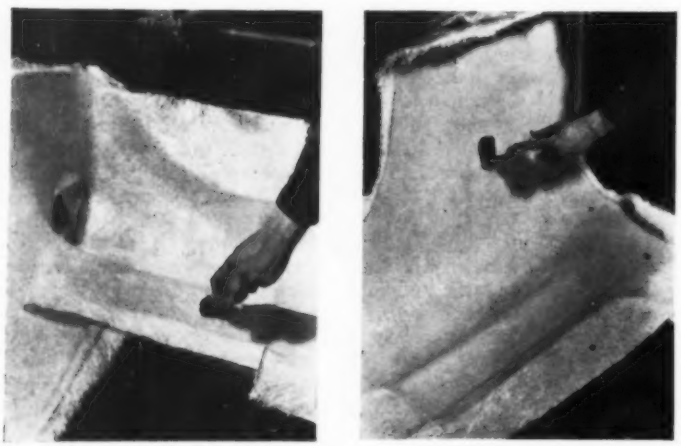
by S. A. GREGORY, B.Sc., M.I.Chem.E.

THE number of types of plastic material used in chemical works specifically for the construction of plant is small. Surface coatings and cements, which demand a different approach in their application, are not considered in this present discussion. Up to perhaps seven to ten years ago the only plastic material likely to be used by the works engineer was of the asbestos-filled phenol formaldehyde resin group, such as "Tufnol" or "Ferobestos". This could be obtained in small sheets, rod and tube. Since then we have seen the emergence of polythene, rigid P.V.C. and reinforced polyester resin (R.P.R.). For some small and particularly arduous duties polytetrafluoroethylene (P.T.F.E.) has been useful. But it is the big three—polythene, P.V.C. and R.P.R.—that have brought about a revolution in the works. Only one other material of construction has had anything approaching a comparable effect in recent years, namely, glass as used in industrial equipment.

Values of the Big Three

From the point of view of the plant constructor, the reason for using either polythene or P.V.C. is the ability to obtain resistance to a wide variety of corrosive materials at low cost. The plant engineer, however, has found that these materials may be readily fabricated without a very high level of skill, and lend themselves to a wealth of applications.

R.P.R. has not yet been much specified by the plant constructor. Its resistance to chemicals depend upon the type of resin used and the care taken in fabrication. However, although R.P.R. may be taken as chemically less resistant than the two thermoplastics, it may be used over a wider temperature range, under some conditions operating as high as 180°C as against the possible limit of 70°C for P.V.C. Further, R.P.R. lends itself to the fabrication of objects involving double curvatures which are less easy to obtain with the thermoplastics. These differences, of course, derive from the fact that polythene and P.V.C. are supplied as sheets and tubes formed by extrusion under temperature conditions favouring plastic flow of these materials, which are thermoplastic. R.P.R., on the other hand, is formed by coating on a mould and reinforcing the still-liquid resin with glass cloth or mat. On completion of the build-up the resin is cured. This resin is, of course, thermosetting and, therefore, does not soften on the application of heat.



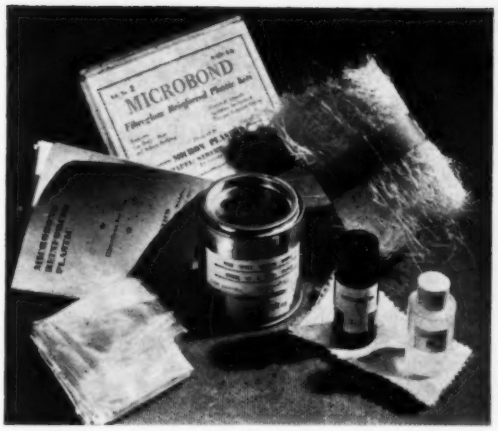
WET LAY-UP TECHNIQUE. (*Left*) *The first layer of glass mat is placed in position on the mould surface and then stippled with resin.* (*Right*) *The resin is then worked into the mat with a special roller. The processes are repeated to build-up laminates of required thickness.*

Just as it is now possible to repair your car at home by covering holes in the body with R.P.R. bought as a kit, so it is possible to carry out repairs to plant by a similar technique. It is this possibility which sets upon the big three the seal of "do-it-yourself".

The virtues of these materials have led to their being tried by many people. The plant engineer, at his wit's end to keep equipment in operating condition; the chemical engineer faced with the need to build a pilot plant which will reach the scrap heap before a commercially built unit can be delivered; the plant development engineer whose task is continually to review possible methods of improving the working life of the equipment under his care; such were the members of the Institution of Chemical Engineers who took part in a recent discussion at Scunthorpe of experiences in the use and fabrication of plastics at their works. Those who attended this meeting came from CIBA, Fisons, Laporte Titanium and Appleby-Frodingham.

(Left) The joints of this 600-gallon brine tank, made from plywood and angle-iron, were sealed with polyester resin and then a laminate layer was built-up inside and outside the box from resin and glass mat.

(Right) To enable repairs to be carried out to reinforced plastics components, a special kit has been marketed. (Photo: Microplas Ltd.)



Polythene

The principal manufacturer of polythene is I.C.I. They provide a booklet describing the chemical and mechanical properties of their "Alkathene" sheet, giving sufficient details for the successful fabrication of the material. The supply of sheet and pipe is in the hands of a number of firms who obtain their raw material from I.C.I.

The most readily available form of polythene is pipe of plumbing grade. This is stocked by the larger builders' merchants and is eminently suitable for chemical use. This pipe is black in colour, being thus pigmented in order to make it suitable for exposure to sunlight. In standard sizes, polythene pipe up to 2 in. diameter is relatively cheap. For example, mild-steel pipe of "B" grade, 1 in. diameter, costs 0.7s/ft, whereas black polythene pipe of the same size (low-pressure grade 2, B.S. 1973) costs 1.5s/ft. For long pipe runs it is possible to use polythene without the need to make many joints, because the standard grades are available in lengths up to 500 ft.

Polythene is not rigid and requires to be supported. In order to prevent sag, it is good practice to provide a continuous support, such as cable tray or light angle. In a comparison of installation cost for a certain supply line some 70 ft in length, it was found that both polythene and mild steel at 1 in. diameter cost 3s/ft overall. In another case, the adaptability of polythene for pipe-work was shown by the laying of an effluent pipe for a distance of 3000 ft by mole-ploughing, the task being essentially completed in eight hours.

It is possible to reinforce polythene pipe or vessels by coating with Araldite 103 resin and wrapping with glass scrim. A case was reported in which a pipe normally failing at 55 psig was thus reinforced to stand operation at 300 psig.

Linings for vessels are readily made in polythene, but because of the high coefficient of thermal expansion such linings tend to slide or buckle for small temperature changes. A suggested limit of size for a mild-steel tank lining is 6 ft × 3 ft × 3 ft. A report was made of lining a timber vessel of 3000 gallons capacity, but here the aim was to salvage the vessel.

For the future, great interest is placed in the new H.D. polythene and the "Marlex" product. One test on H.D. polythene tube showed that it would break-down on passing 30 psig steam through it, but that it would withstand steam at 20 lb.

Rigid P.V.C.

The manufacturers of vinyl chloride monomer are British Geon and I.C.I. The polymerised material is available in the form of sheet and pipe from a number of firms who extrude the product. The chemical and mechanical properties are described in brochures supplied by these manufacturers.

Rigid P.V.C. is cheaper as sheet than polythene. Thus ¼-in. material costs 11s sq. ft, as against 12.5s for polythene or 2.5s for mild steel. Not only is P.V.C. somewhat cheaper as a material than polythene, but it is slightly cheaper in welding, since it is possible to use hot air as compared with the hot nitrogen required for polythene. The size of P.V.C. sheets available is now quite large and this helps to keep down the cost of fabrication. P.V.C. may also be joined by the application of suitable solvents.

P.V.C. lends itself particularly to the fabrication of large ducting and cylindrical vessels of restricted diameter. For large-bore piping, P.V.C. has shown itself to be competitive with mild steel when overall costs are considered. For a 5-in. diameter effluent pipe it was found that P.V.C. construction cost £64, which was the same price quoted for laying a mild-steel pipe with couplings. An important element in this cheapness of P.V.C. appears to be the ease of handling.

In general, ductwork of rectangular section is easier to fabricate than in circular section, since the latter requires hot forming. Such ducts need to be supported and protected from vibration. An expansion allowance of 6 in. 15 ft is recommended. P.V.C. piping has, up to the present, appeared to be less economical than the standard piping available in polythene. However, the situation may change. Because of its rigidity and ease of fabrication, P.V.C. lends itself to the construction of small moving equipment such as valves, pumps and fans. But care should be taken to protect such items from shock, particularly where hazardous materials are handled.

Reinforced Polyester Resin

The methods of constructing items from R.P.R. are given in booklets supplied by the manufacturers of the resin. Suitable firms are Scott Bader & Co. Ltd., British Resin Products Ltd. and Bakelite Ltd. There are different varieties of these resins available and some have much better resistance to chemicals and heat than others. For a particular application it is recommended to try a sample of the resins first. Much of the material published on the range of applicability of R.P.R. may be misleading because of the type of resin used, or the incorrect choice of glass reinforcement, or because of inadequate fabrication technique.

The possibilities of R.P.R. application in the works are

quite exciting. For example, one firm was faced with the need to replace a stainless-steel plate used in a granulator and measuring 8 ft × 4 ft × ⅜ in. thick and pierced with about a thousand ¼-in. holes. Because it was found that the holes in the equipment as delivered were wrongly sized and located, there was an urgent need to procure a replacement at a time when stainless steel deliveries took twelve months. The proposed use of brass was limited by the required delivery of four months. R.P.R. was suggested and, after the timber former had been made, it took only twenty-four hours to finish the plate, which was readily perforated to the correct specification by a standard electric drill.

On another occasion the hard rubber covering of a rotary vacuum filter was faulty and acid attacked the underlying steel. The bad rubber was removed and a patch of R.P.R. applied in its place. For this task the machine was only out of operation two days.

A stainless-steel fume hood handling acid materials lasted only six weeks. This was replaced by a mild-steel duct lined with R.P.R. at a cost of £100; some £200 less than the cost of the original stainless-steel item. Today such ducts are made solely from R.P.R. and cost about 10s/sq. ft of material.

The experiences quoted justify the development of the "do-it-yourself" method in these works. Instead of having to rely upon outside specialists to produce relatively expensive items at extended delivery times, the prospect now exists of making small items and carrying out urgent repairs at short notice on the factory premises. So valuable has this new facility become, that a number of works have set up a plastics fabrication section or have trained a suitable technician to use the materials. In some cases the chemical plumber has been brought up to date and includes the fabrication of plastics in his repertoire. However, for the new-comer, it is important to go carefully. Tests should be made regarding proposed new applications. But do not be put off too much by such warnings. Substantial savings in capital cost and possibilities of reduced maintenance can come from "do it yourself".

The 600-gallon tank shown on p. 29 was made at the Orgreave Works of United Coke & Chemicals Co. Ltd. The picture is reproduced from a useful article by J. Norris and H. L. Riley in *The Gas World* (Special Supplement), March 5, 1955, p. 55.

HEAT-TRANSFER EXPERIMENTS WITH EXTENDED SURFACES

At a symposium on the Calder Works Nuclear Power Plant, organised by the British Nuclear Energy Conference, and held in London last month under the chairmanship of Sir John Cockcroft, one whole session was allocated to a discussion on papers on research. During this session a paper entitled "Heat-transfer Experiments on the Fuel Elements" was presented by P. Fortescue and W. R. Hall. An abstract of this paper and a summary of the ensuing discussion are given below.

SYMBOLS USED

f = friction factor $\Delta p = \frac{4fl}{d_e} \cdot \frac{\rho v^2}{2}$;
f_o = friction factor for smooth-walled passage;
k = thermal conductivity of gas;
k_m = thermal conductivity of fin material;
Re = Reynolds number;
St = Stanton number;
St_o = Stanton number for smooth-walled passage;
$\psi(x)$ = function of x.

THE longitudinally-finned fuel elements of the Windscale reactors were the starting point of the work that led to the type of heat-transfer surface employed on the Calder Hall fuel element. The transverse-finned element used in the reactors evolved largely from attempts to rectify certain observed failings of longitudinal fins. A survey of experimental data on various compact types of heat-transfer surface suggested that, if economy of pumping power was to be a criterion, smooth longitudinal fins would give the best results. Preliminary design calculations were based, in the absence of experimental data, on the assumption that the finned can and channel assembly could be compared with a tube of the same "effective diameter". Subsequent experiment proved this to be incorrect, but not excessively so, the heat-transfer coefficients falling short of the predicted values by about 30% in the worst cases.

It soon became evident from the early heat-transfer measurements made at A.E.R.E. that lack of mixing of the coolant in a radial direction was the main cause of the discrepancy between experimental and predicted heat-transfer coefficients. Experiments with a transverse fin used by Wyatt and Huddle proved the fin to be surprisingly efficient when compared with the longitudinal fin. It has since been shown that there is a systematic flow between the fins, generally in the form of two vortices "geared" together.

Heat-transfer and pressure-drop measurements were made with longitudinal fins at R. & D. B., Windscale, using a test rig that simulated reactor conditions. A 20-ft channel of elements each 1 ft long was tested for a range of elements having from 0 to 16 fins of lengths between 0 and 1 in., the fin thickness in all cases being 0.02 in. The temperature at the can surface between two fins and the heat input were measured for each element. Thus the distribution of heat-transfer coefficient along the channel could be measured.

It was found that the results, when corrected for fin efficiency, could be expressed with an accuracy of about ± 7% by the equations:

$$St = 0.04e^{-0.055n} . Re^{-0.2}$$

and

$$f = 0.083\, e^{-0.028n} . Re^{-0.2}$$

where n = number of fins. Reasonably good correlation is obtained by using equations that do not involve the length of the fins.

Studies on temperature distribution across channels and the use of mixing devices demonstrated that lack of mixing of the air between the fins with that in the outer regions of the channel is a serious defect of this type of fin. The effect of one of the more efficient types of mixing device is to increase the output. For a given pumping power this can be increased by 10-20%. These devices need only be used at the hottest region of the channel.

The first measurements on transverse-finned elements

were made by Leicester at A.E.R.E. The variation in Stanton number and friction factor with Reynolds number was similar to that for a smooth tube over the narrow range tested (*Re of* 1×10^5 to 2×10^5). Consequently the results could be expressed in the form shown in Fig. 6. The results, both for friction factor and Stanton number, are compared with the corresponding values for a solid rod of diameter d_f. The values for the solid rod are taken to be:

$$f_0 = 0.046Re^{-0.2}$$

$$St_0 = \frac{f_0}{2-3.86\sqrt{f_0}}$$

based on von Kármán's analogy.

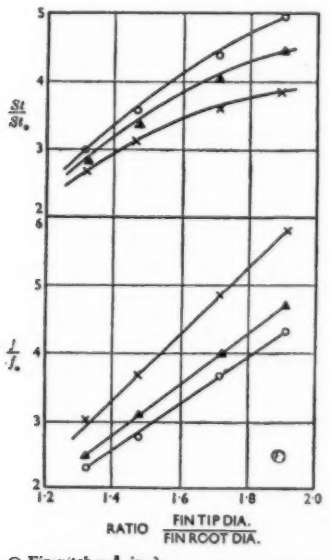
Both the heat-transfer and pressure-drop results indicate an advantage in choosing close-pitched fins. Subsequent experiments were therefore made with fin pitches of $\frac{3}{16}$ in. or less. Roberts, at A.E.R.E., extended Leicester's measurements by testing fins of diameters ranging from $1\frac{1}{4}$ in. to $2\frac{1}{4}$ in. pitched at $\frac{1}{8}$ in. and $\frac{3}{16}$ in. in channels of 3 in., $3\frac{1}{2}$ in. and 4 in. dia. These results, covering a wider range of Reynolds number than Leicester's, show that whilst the friction factor does not vary greatly with Reynolds number, the same cannot be said of the Stanton number. This effect may be attributed, in part at least, to a reduction in fin efficiency as Reynolds number is increased.

Experiments designed to isolate the effect of fin efficiency on the heat transfer from transverse fins have been carried out by Roberts and Husain at A.E.R.E. Roberts has shown that for the range of variables covered in these experiments,

$$St = \psi\left(Re \cdot \frac{k}{k_m}\right)$$

the Prandtl-number variation being neglected, since there is little variation between gases in this respect. The experiment using the air-cooled apparatus is not an entirely satisfactory test of the above equation, and it is desirable to use a pressurised apparatus to establish the validity of the equation.

The detailed coolant-velocity distribution in the space between two fins has been measured at Windscale. The apparatus consists of a rectangular section channel with transverse fins on the lower wall, air being drawn through the apparatus by means of an axial-flow fan. As the air velocity between the fins was measured by means of a hot-wire anemometer, only the magnitude and not the direction of the air flow could be measured. Work is proceeding using a hot-wire "yawmeter" so that a more complete picture of flow may be obtained.



St, *f* = Stanton number and friction factor for transverse finned rod.
St_0, f_0 = Stanton number and friction factor for solid rod (see text).

Notes: The heat-transfer area for the finned rod is taken as the cylindrical surface enclosing the fin tips, i.e. the same as for the solid rod.
The effective diameter for the finned rod and channel is $d_e = d_c - d_f$, i.e. the same as for the solid rod and channel

Fig. 6. Comparison of heat transfer and pressure drop for transverse-finned rod and a solid rod of the same outside diameter (Leicester, A.E.R.E.).

Discussion

Prof. O. A. SAUNDERS (City and Guilds College) suggested that a direct comparison of the two fin systems in regard to heat transfer and friction under the conditions met in a reactor would be useful. Referring to the effect of finite temperature difference upon the heat-transfer coefficient mentioned by the authors, he said that it seemed to him that in a reactor channel the conditions varied greatly from one end to the other. At the inlet, where the coolant was uniform, the finite temperature-difference effect would presumably be greatest, whereas when approaching the outlet end that effect must be less. He suspected that the value of *a* used by the authors, 0.32, for correcting for this effect was really a mean value for the particular set-up. It was very difficult, from the results given, to disentangle the true finite temperature-difference effect from the bad mixing effect, and this must be done to get results which were to have a broader application.

Dr. B. F. J. SCHONLAND (United Kingdom Atomic Energy Authority) asked if the authors could say whether or not circumferential fins of the ranges of proportions discussed by them would be appropriate also for higher temperatures and higher power densities? Under such conditions, it might be necessary to use materials of a different nature and of poorer conductivity.

Mr. R. D. VAUGHAN (Nuclear Power Plant Co. Ltd.) said that the authors had described the transverse fin as "efficient" when compared with the longitudinal fins employed in the Windscale reactors. He suggested that this was a wrong use of "efficiency" and that a more practical definition might be the ratio of Stanton number to friction factor. This ratio was an indication of the heat-extraction rate over the blowing power for a given mass flow in the channel.

Mr. P. H. MARGEN (Atomic Energy Co. of Sweden) said that he had examined the results in the paper in a way which correlated Stanton number and friction number. The analysis indicated that the packing used was of a "good" type.

Mr. D. W. GINNS (I.C.I. Ltd.) described as "somewhat surprising" results of the authors which showed the Stanton number rising faster than the friction factor. He thought that this was probably due to the use of the special parameters.

Dr. K. J. WOOTTON (Simon-Carves Atomic Energy Group) said that heat-transfer and friction factors derived from air tests at Reynolds numbers over 1.5×10^5 should be treated with some reserve. The extrapolation of air-rig tests at Reynolds numbers of 1.5×10^5 and less up to reactor conditions of 3.5×10^5, the figure which the authors mention, obviously introduced further uncertainties.

The paper and discussion will be printed in full in *The Journal of the British Nuclear Energy Conference.*

An air-cooled condenser of German manufacture designed to condense 40 tons of steam per hour from turbines. The chimneys provide natural draught and prevent hot air recirculation.

AIR-COOLED HEAT EXCHANGERS*

by D. KAYE, B.Sc. (Eng.) Chem. Eng.

INDUSTRIAL applications of air-cooled heat exchangers, in addition to those of diesel-engine cooling and steam condensing already discussed, are summarised below:

(1) In the chemical and petroleum industries air coolers are used for the condensation and cooling of hydrocarbons, petrochemicals, acids and alkalis. Where condensation temperatures are very high, air cooling can be considerably cheaper than water cooling. Notably, air coolers avoid the difficulty, always present with water-cooled equipment, of scale formation and the consequent need for the heat exchanger to be over-dimensioned, or for complete spare units always to be available. Also, with water-cooled equipment high condensation temperatures usually produce very hot cooling water and this deteriorates the wood contained in most cooling towers.

(2) Air coolers have been used to cool water from burners and furnaces which require recirculated cooling water.

(3) The cooling of quenching oils, where a proportion of the quench bath oil is continuously recirculated and cooled, may be undertaken with air coolers.

(4) Air coolers are used extensively in the electrical industry, for example, in transformer-oil cooling. Air flowing by natural convection, or blast air may be used in the process. The exchangers have also been used for cooling radio and television transmission equipment.

(5) Units have been used successfully for vaporising. For example, in the oxygen industry liquefied gases have been vaporised and heated using an air blast over finned tubes. Great care must be taken to avoid frosting.

(6) One of the largest applications of finned-tube units is in heating and ventilating installations. Here air is heated by water or steam in the tubes, and the hot air produced by this process is used for heating purposes.

(7) The refrigeration industry affords a wide field of application for finned-tube units both on the vaporising and condensing sections. Air-cooled heat exchangers with either forced or natural draught are used extensively for the condensation of ammonia, freon and CO_2.

(8) Air coolers have been used for interstage compressor coolers. They are particularly suitable for this application when the compressors are used for wind-tunnel work where ingress of water on the air system must be avoided. When in the vicinity of wind tunnels, cooling towers, necessary with water-cooled systems, add to the danger of having moist air at the intake to the compressors.

The field of application of air-cooled heat exchangers, wide as it is at present, will probably become even more varied with development or manufacturing methods and increasing costs of cooling water.

The advantages of air-cooled systems may be summarised as follows:

(1) No water make-up is required.

(2) Scaling in heat exchangers can be avoided.

(3) No water treatment is required.

(4) The life of air-cooled units is practically unlimited.

(5) Very little maintenance is necessary. Finned tubes can be cleaned easily using compressed air or water.

(6) Cost of air-fan power is always less than cost of equivalent make-up water.

(7) There is no danger of leakage of water to the product.

(8) Product temperatures are easily controlled and considerable power savings can be achieved by using two-speed motors or variable-pitch fans, the pitch of which may be automatically controlled by the temperature of the cooled product.

* Continued from *British Chemical Engineering*, 1956, **1**, 415.

TABLE 3.—Summary of economic study comparing the use of an air-cooled system, with a heat-exchanger/cooling-tower system.

	Heat Exchanger plus Cooling-tower System	Air-cooled Heat Exchanger System	
		Case 1	Case 2
1. FIXED CHARGES £1000 p.a.			
Exchangers	8·20	23·3	29·0
Cooling-towers	4·76		
Pipeline	12·00		
Pumps	·47		
Water Softeners	1·50		
Total fixed charges	26·93	23·3	29·0
2. RUNNING COSTS £1000 p.a.			
Pumping through exchangers	0·89		
Pumping up towers	4·76		
Pumping through pipeline	1·02		
Total pumps	6·67		
Total fans	5·99	25·8	14·0
Total power	12·66	25·8	14·0
Water	23·64		
Total running costs	36·30	25·8	14·0
Total fixed charges	26·93	23·3	29·0
Total costs p.a.	63·23	49·1	43·0
Pump h.p.	218		
Fan h.p.	195	830	450
Total h.p.	413	830	450
Air flow lb/hr/ft^2		4000	3000
Heat Load x 10^6 Btu/hr	273	273	273

(9) The operation of air-cooled units is trouble-free and continuous so long as the system is adequately vented and all non-condensable gases are allowed to escape.

(10) An air-cooled system usually takes up less space than a cooling tower system.

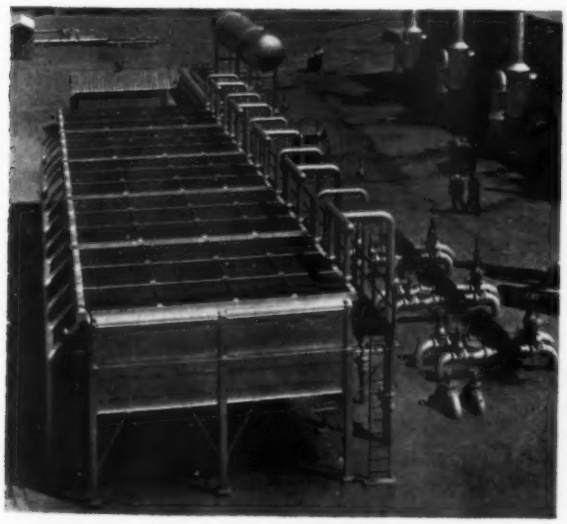
(11) There are no spray losses to cause nuisance.

As an example of a cost comparison, results of an exhaustive and careful study made recently are given in Table 3. The duty considered in this case was 273 × 10^6 Btu/hr and process water was cooled from 142°F to 86°F, with a wet-bulb temperature of 60°F and a dry-bulb temperature of 68°F. The most economic case for the water-cooling system has been selected from calculations involving five cooling-tower water ranges and four cooling-tower approach temperatures. The most economic case for cooling towers was obtained when the range was 50°F and the approach 10°F. This, incidentally, illustrates the importance of selecting the correct cooling-tower duty when investigating the performance of cooling towers, as great savings can be made by co-ordinating the cooling-tower duty with the heat-exchanger duty. Easy duties for cooling towers lead to low cooling-tower costs but increased heat-exchanger costs, and the most economic arrangement must be obtained.

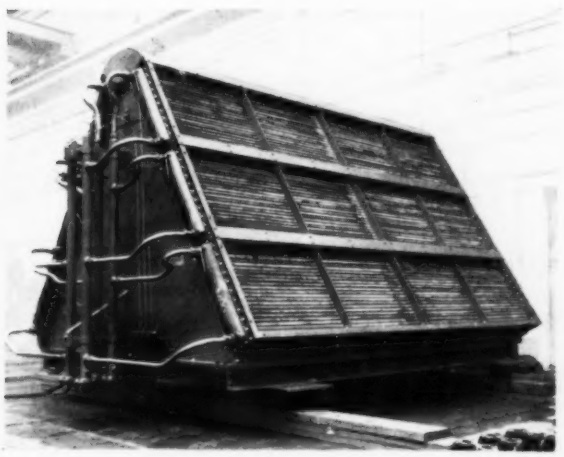
The most economic case for the air-cooled system is obtained by varying the number of rows of tubes in an element and the mass-flow of air. The number of rows of tubes investigated were four, six, eight and twelve, and four different air flows were considered. It was found that the most economic case for air coolers was obtained when the air flow was 3000 lb/hr/ft^2 and the tubes arranged six deep. Fixed charges have been taken as 10% of the total capital cost. This includes depreciation with a plant life of twenty years, interest on capital and maintenance. With regard to running costs, only fan horse-power need be considered for an air-cooled system, but, with water cooling, pumping costs in heat exchangers, in pipes and cooling towers, as well as fan costs for the towers, must be taken into account.

In air-cooled systems the only capital cost is for the air-coolers, but with water-cooled systems costs of water/water heat exchangers, cooling towers, pipe-lines, pumps and water softeners are also involved. An important cost with a cooling-tower system is that of make-up water, which, as can be seen, is as high as the air-cooled system capital costs. The cost includes that for chemicals for water treatment, and for water to make good the evaporation loss.

From Table 3 it may be seen that total costs per annum can be substantially less for the air-cooled systems. Case 1 gives details to show that capital costs can be less than for an equivalent cooling-tower system. The percentage saving in total costs per annum is 22% in case 1 and 32% in case 2. The figures apply to an installation for continuous full-load operation. The case for air cooling is even more attractive when part loading is considered.



A typical illustration of horizontal cooling elements for cooling water from a diesel-engine station. The elements operate independently.



An "A"-type structure of cooling elements for diesel-engine cooling. It can be seen that the banks of finned tubes are horizontally arranged.

THE N.C.B.'s CHESTERFIELD COKING AND BY-PRODUCTS PLANT

THE recently commissioned coke and chemicals plant of the National Coal Board at Chesterfield contains a number of remarkable features not to be found in other coke-oven plants. The conception of the entire plant has led to a highly flexible and integrated undertaking capable of producing from very low grade coal a smokeless fuel suitable for domestic and industrial consumption. Sufficiently flexible to produce metallurgical coke should conditions demand it, the plant layout has been arranged for the installation of additional ovens to double its capacity. The gas-purification and by-products plants are already capable of dealing with double the quantity of coke-oven gas and purified by-products than they treat at present.

Another feature illustrating the flexibility of design concerns the disposal of pitch. It is a peculiarity of the pitch market that the demand for it is either very high or very low, hence the phrase "pitch is either a feast or a famine". In order to reduce an accumulation of unsaleable pitch at periods of low saleability, it is possible to produce at the pitch plant a hard pitch which can be blended in with the coal fed to the ovens. In this way 50% of the pitch produced can be returned to the ovens. Among the innovations is the use of coke ovens, generally looked upon as a source of metallurgical coke, for the manufacture of domestic coke. Other outstanding features of the plant are:

(1) The dilution of the coke-oven gas with producer gas to give a fuel of the calorific value desired by the Gas Board.

(2) The design of the ovens is such that they may be fired either by coke-oven gas, which is the fuel normally used, or producer gas. The producer plant can provide fuel for operating about a third of the total number of ovens, and this is sufficient to keep the entire oven battery warm in the event of severe interruption of production at the ovens.

(3) Removal of H_2S from the combined gas stream including that fed back to the ovens. This practice overcomes the difficulty of removing sulphur from the flue gases and is justified by the additional sulphur recovery which is sufficient to render the plant self-supporting in its sulphuric-acid requirements.

(4) The recovery of sulphur from spent oxide by Flixborough-type rotary burners for the production of sulphur dioxide feed for the sulphuric-acid plant.

(5) The use of a Kachkaroff plant for sulphuric-acid manufacture. This type of plant is used because spent oxide is not usually a suitable source of SO_2 for the contact process.

(6) In the tar acids and bases extraction plant the conventional method of extracting naphthalene by whizzing and hot pressing is not used. Instead, a method of liquid extraction using methanol is employed and is capable of producing a pure naphthalene, suitable, for example, for phthalic-anhydride manufacture.

(7) The waste liquor from the base of the ammonia column at the ammonium sulphate plant cannot be discharged to natural waterways because of its high oxygen absorption and toxicity. The various harmful impurities, such as thiocyanates, thiosulphates and phenols, are removed in the effluent treatment plant by a process of ion exchange and adsorption. Some of the impurities, such as the phenols, are recovered from this plant, others are concentrated to a very small volume in a submerged combustion evaporator.

(8) Finally, there is the power plant and the provision of alternative drives employing either steam or electrical power for some of the moving machinery, e.g., exhausters which consume large amounts of power. This is a measure which has been adopted in order to give the most economical balance of process heat and power in harmony with the coke-breeze supply available for firing the boilers.

The following are some details of the plant:

Cost	£10½ million
Maximum gas output ...	27 million cu. ft/day
Gas to Gas Board ...	14 million cu. ft/day
(This may be increased to 18 million cu. ft if full use is made of the producer gas plant.)	
Coke output	1400 tons/day
Coal consumption ...	2175 tons/day
Capacity of by-product plant	By-products from 4500 tons coal/day
Capacity of benzole plant	20,000 gallons/day crude benzole
Capacity of tar plant ...	200 tons/day tar treated
Ammonium sulphate plant	35 tons/day
Sulphuric acid plant ...	50 tons/day
Total number of coke ovens	106 (two batteries)

From the chemical engineering angle, apart from the carbonising process proper, the remainder of the plant is of special interest. This is particularly true of the purification system, including the removal of tar, ammonia, naphthalene, and the by-products plants.

Coke Ovens and the Carbonising Process

The basic raw material for the plant is coal obtained from pits within a radius of six or seven miles of the plant. The charge fed to the coke ovens has a volatile content of about 38 to 39% with an ash content of around 10.

In the ovens the intention is that the centre of the charge should be around 800°C, whereas in the combustion space the temperature is in the range 1300 to 1350°C. The coking process produces, apart from coke, a variety of chemicals, some of which have to be removed from the gas as they can cause blockages in the equipment, give undesirable combustion products, or reduce the calorific value of the gas. Some of the products are removed on account of their value as by-products.

The mains for each battery of 53 ovens are interconnected by means of a bridge-trunking in which two fans are installed for discharging the c.o.g. into a common main leading to the primary coolers and the remainder of the treatment plant. These fans operate alternately at three to five-minute intervals. Any one fan will pump a large proportion of the crude gas to the primary coolers, leaving the remainder to pass through the idle fan to the main on the opposite side of the oven from which the gas is being withdrawn. The gas is thus recirculated backwards and

forwards through the coke ovens.

The ascension pipes at the ovens terminate at the collecting mains by means of sharp return bends in which are fitted sprays for the flushing liquor. Additional sprays are fitted in the collecting mains opposite alternate ovens. The liquor discharges from the mains by means of liquor-sealed bleeders which allow it to return to the tanks provided for separating tar from the main body of the liquor. The purpose of the sprays is to remove tar and other heavy bodies and to absorb ammonia. The circulation system for the flushing liquor is shown in Fig. 2.

Naphthalene Washing

The naphthalene concentration of the c.o.g. has to be reduced enough to allow the later stages of gas purification to be carried out satisfactorily and to prevent deposits of naphthalene in pipe-lines and at other parts of the plant. There must also be no possibility of naphthalene condensing in the lines feeding gas to the consumer.

Modern practice, of which the Avenue plant is a good example, is to install the washers up-stream of the secondary condensers and between the benzole scrubbers and the oxide towers. The advantages derived from this method of installation are that blockages are avoided at the secondary condensers and light oils, which would otherwise interfere with the subsequent ammonia washing process, are removed. Excessive naphthalene at the H_2S-removal plant would impair the activity of the iron-oxide for final purification.

The washers, which are designed to reduce the naphthalene content to around two grains per hundred cubic feet of c.o.g., employ anthracene oil as the washing medium. A total of four washers, two for each gas stream, are provided at each stage of washing. Since the oil-to-gas flow ratio is very low in the washers, normal tower scrubbers are not used as the liquor rates would be insufficient to wet the packings. This difficulty is overcome by recirculating the anthracene oil at a high rate over a system of towers arranged in series, in which liquor overflows from the base of each tower to the next. In this manner, the counter-current principle is to some extent preserved.

The washers used at Avenue are of a type wherein four towers are combined into a single washer with pumps recirculating the liquor over each section. The anthracene oil containing naphthalene is fed to a regeneration plant, as shown in Fig. 3, and the naphthalene-xylene fraction is separated and fed to the tar-receiving tank. The stripped oil is returned to storage for re-use in the washing process.

Ammonia Washing

The aim here, apart from its recovery, is to reduce the ammonia concentration in the gas to a level which will not interfere with the working of the H_2S-removal plant. Although a concentration of the order of five grains per hundred cubic feet is generally regarded as beneficial, at Avenue the ammonia concentration of the gas reaching the oxide towers is about one-tenth of this figure.

The plant provided for ammonia absorption, apart from the flushing system at the collecting mains and the primary condensers, consists of six washers identical in design with the naphthalene scrubbers. The same considerations of liquor-to-gas ratio apply as for the naphthalene scrubbers. Three washers are arranged in series for treating each gas stream, the washing agent being weak liquor bled from the flushing liquor main. The final washer uses soft water in order to get as complete a removal of ammonia as possible. (See Fig. 2.)

Effluent Treatment

The ammonia, fixed and free, is obtained from the strong ammonia liquor by a process of straight distillation combined with chemical reaction in which the agent for releasing fixed ammonia is lime. The discharge from the "fixed-still" base contains calcium chloride, thiosulphates, phenols and other organic materials such as tar acids. The disposal of this kind of liquor is a formidable problem and has been a troublesome one for many years at a number of plants. As mentioned earlier, its poisonous nature and its high oxygen demand have precluded its discharge to rivers. Furthermore, it cannot be disposed of to the domestic sewers, since the quantity that these can accept must be less than one-half per cent of the dry weather flow.

The method finally adopted at Avenue is shown in a simplified form in Fig. 4. In this process the cooled effluent is dosed with hydrochloric acid, pumped through an ion-exchange bed of the medium-base type for removal of thiosulphates and thiocyanates. Tar acids and phenols are removed by adsorption on activated charcoal. The regeneration of the exchange material is brought about by treatment with ammonia with the resulting liquor further treated for ammonia recovery by reaction with lime slurry. For this purpose an ammonia-recovery system is provided. The bottom product from the fixed ammonia column of this system is concentrated to about one hundredth of its original volume before it is stored for dumping. The ammonia derived is fed to the sulphate plant.

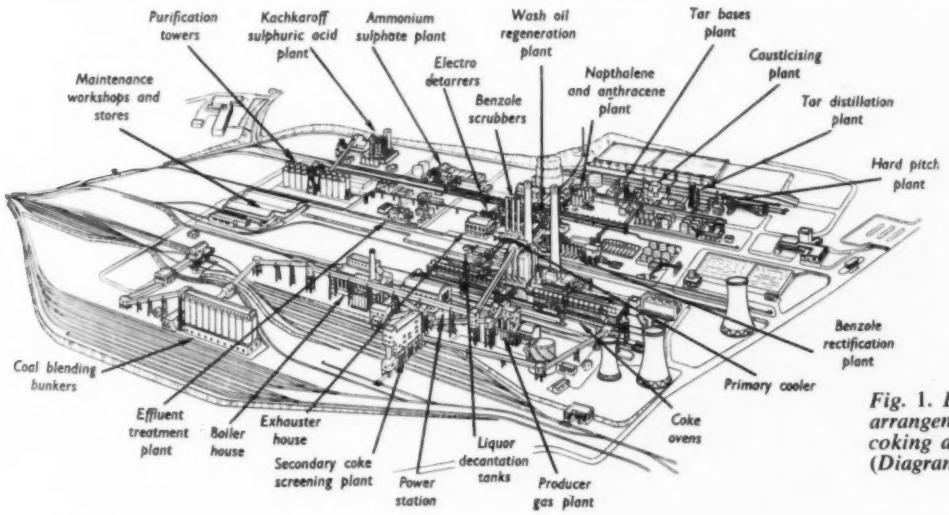


Fig. 1. Diagram showing the arrangement of the Avenue coking and by-product plant. (Diagram: Woodhall - Duckham Ltd.)

The carbon is regenerated by washing with benzole (3% benzene) which is separated by distillation from the phenols and tar acids. The reject liquor containing these materials is treated in the tar-distillation plant.

The treatment thus given to the effluent is capable of producing the following result:

	Raw Liquor	*Liquor ex Plant*
Turbidity ...	... Up to 2000 ppm	< 5 ppm
Colour ...	... Dirty brown	Water white
pH ...	... 9-10	7-9
Thiocyanate	... 230 ppm	0.40 ppm
Thiocyanate	... 150 ppm	< 10 ppm
Phenol ...	... 750-1000 ppm	< 10 ppm

Tar Treatment

The crude tar separated at various stages in the purification process is treated to yield a variety of products. The first stage of tar treatment is the fractionation of the crude tar; the resultant products are withdrawn at different trays of a single distillation column. The products are benzole, naphtha, carbolic oil, naphthalene oil, creosote oil and anthracene oil. The bottom product is pitch and depending upon market conditions, its hardness can be varied at will, since the design of the distillation unit is sufficiently flexible to allow this.

When the market conditions for pitch are difficult, as mentioned earlier, a hard 120° pitch is aimed at. This, when blended with coal in the ratio of 1:3 and mixed with anthracene oil, is suitable for charging the ovens.

The carbolic and naphthalene oils are treated separately to release the tar acids and tar bases, such as pyridene, naphthalene and anthracene, are also extracted from the products of distillation.

Naphthalene Extraction

As indicated earlier, the naphthalene extraction from naphthalene oil represents a new departure in this field. In outline, the process consists of treating the crude naphthalene oil previously admixed with drained oil from the early stages of the extraction process. The charge is pumped to one of a group of specially designed crystallisers in which it is subjected to controlled cooling over a period of about three days. The mother liquor obtained from the drainage process is returned, in part, to the incoming crude oil and the rest pumped away for disposal. The material remaining in a crystalliser following this treatment consists of crude naphthalene crystals, which are then washed with methanol returned from a previous washing process. The methanol is then drained from the vessel and, after a period of time, a further charge of pure methanol is introduced. Subsequently, the methanol is allowed to drain away and the residual methanol is then expelled by the application of heat to the vessel and recovered by condensation. The molten naphthalene left in the vessel is drained away and pumped to a combined cooling and flaking machine, from which it is collected in a hopper for bagging and weighing.

Benzole Recovery

After passing through the ammonia and secondary naphthalene washers, the gas is passed through three grid-packed scrubbers arranged in series, the absorbent in this case is creosote oil. The absorbed CS_2, benzene, toluene, xylene, naphtha and any other materials absorbed are removed from the oil by a steam stripping process. The cooled debenzolised creosote oil is returned to the benzole scrubbers.

The separated benzole fraction from the stripping process, which includes CS_2 is fractionated to release the separate constituents. An entire plant is set aside for this purpose. The residues from the naphtha separation are sent to the tar plant for further treatment.

Gas Purification — H_2S Removal

The purification process employed has the function of reducing the H_2S content of the entire gas stream, including that fed back for firing the ovens, from about 7-10 grains per cu. ft. to less than $\frac{1}{2}$ ppm. In a simplified way, the reactions taking place in the process may be represented by the following equations:

$$Fe_2O_3.H_2O + 3H_2S \rightleftharpoons Fe_2S_3.H_2O + 3H_2O$$

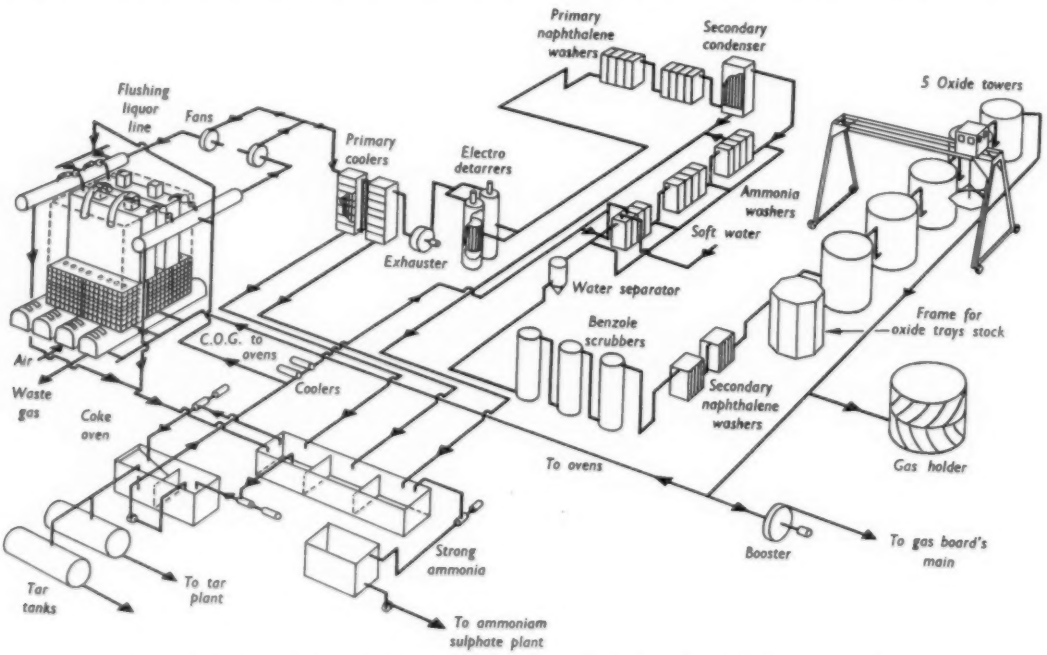
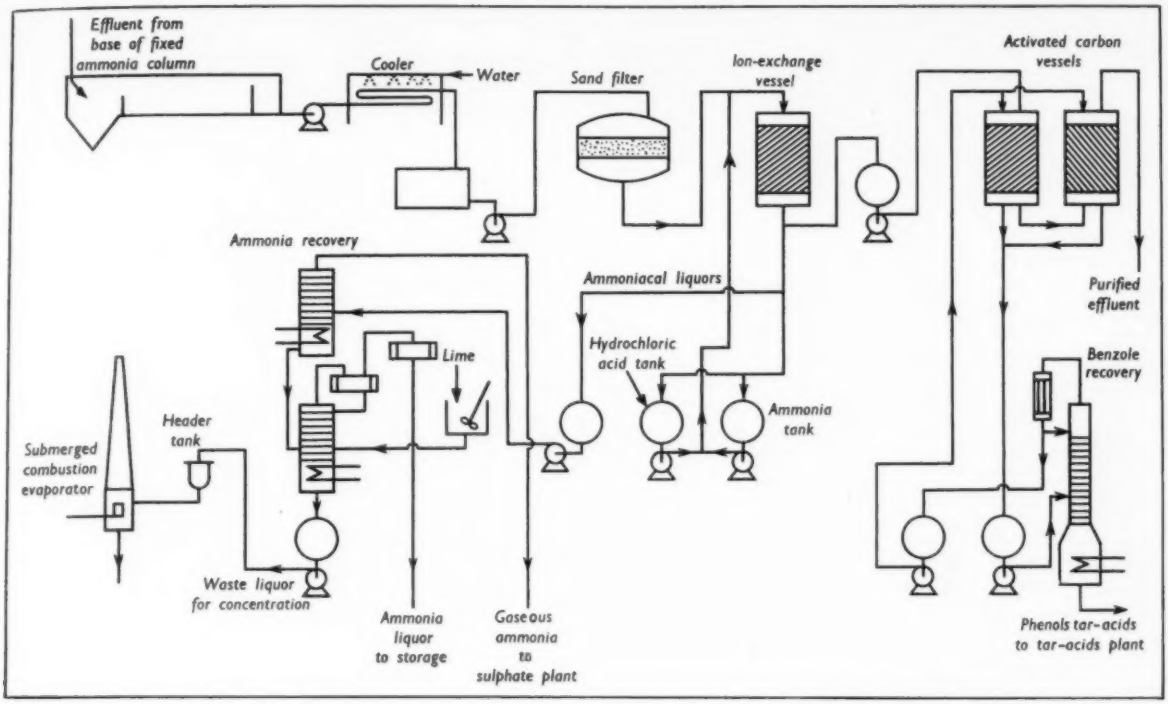


Fig. 2. Purification system for coke-oven gas, including flushing liquor circuit.



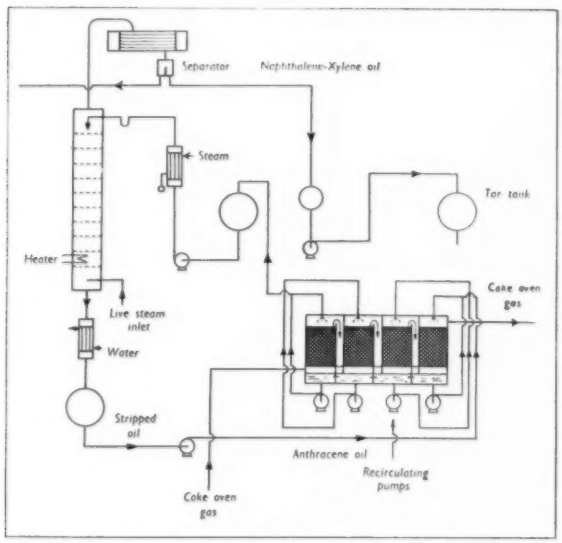


Fig. 3 (left). System for removing naphthalene from coke-oven gas stream. Fig. 4 (above). A simplified diagram of the effluent-treatment plant at Avenue.

The oxide is regenerated by the action of oxygen according to the equation:

$$Fe_2S_3H_2O + 3O_2 \rightleftharpoons 2Fe_2O_3.H_2O + 6S$$

At this plant 2-3% of air is fed in with the main stream of gas to be purified, as this enables both processes to proceed simultaneously until the activity of the oxide begins to fall off.

The purifier employed at Avenue is of the tower box type and five are provided for each gas stream, making ten in all. In addition, a so-called stocking frame is provided on each stream for storage of spare trays of active oxide. There are, in addition, two towers for receiving the trays of spent oxide. Each tower is about 22 ft in diameter × 65 ft high and contains 15 trays or containers, each holding about 25 tons of oxide. The removal and charging operations are carried out by means of a travelling crane whose frame straddles both sets of towers (Fig. 2). An important feature of this system of handling is that an exhausted tower can be taken out of service, recharged and put back into use in three to four hours.

The oxide receives two treatments, depending upon whether it is to be completely revivified or reduced in size prior to reuse. The equipment available, including hoppers, conveyors and a charging turn-table, enables a mixture of partially-spent material and new or freshly revivified oxide to be fed to the towers.

The advantages of this system of purification, with its massive towers, storage frames and lifting apparatus, over the alternative system of elevated boxes, particularly for a throughput of the magnitude to be found here, is a great saving in labour and ground space occupied.

Treatment of Spent Oxide

The oxide, at exhaustion, contains about 46-48% sulphur, which is recovered as sulphur dioxide for conversion to sulphuric acid in the Kachkaroff plant. The oxide is ignited at about 680°C in a pair of rotary burners of a type developed by Nitrogen Fertilisers at Flixborough. One marked advantage of this system is that after treatment and mixing with peat and sawdust no additional revivifying material need be added to the oxide cinder. This factor has an important bearing upon the economics of the H_2S-removal process, and is one which led to the decision to use Flixborough burners.

The SO_2 content of gases leaving the burners is 5-6%. The conversion to SO_3 is accomplished by means of the interaction of the dioxide, oxygen and nitrogen oxides contained in sulphuric acid (nitrous vitriol). This reaction, which occurs rapidly with regeneration of the nitrous vitriol, is carried out in a tower reaction system. The make-up oxides of nitrogen introduced into this system are obtained from a small ammonia oxidation unit which is used only occasionally.

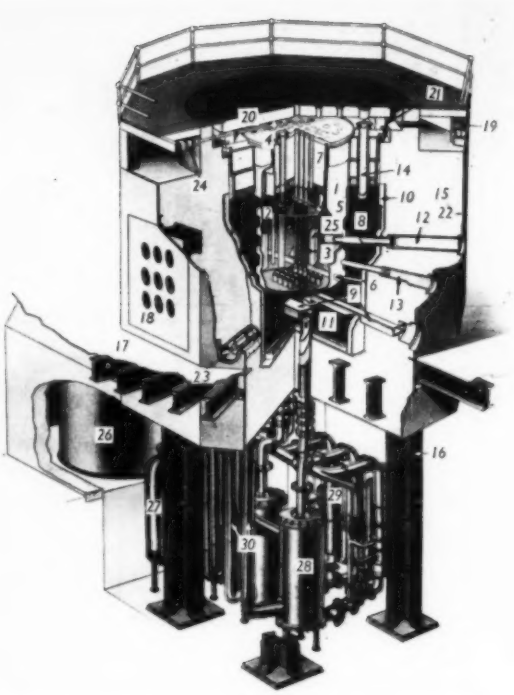
HARWELL'S LATEST MATERIALS-TESTING REACTOR

THE new Dido reactor at Harwell, which recently commenced operation at power, is an important addition to the Atomic Energy Authority's research tools. It is a heavy-water-moderated reactor using enriched uranium fuel, has a maximum heat output of 10 mega-watt, is the most powerful reactor of its kind in Western Europe and it will provide a neutron intensity of forty times that previously available in Britain.

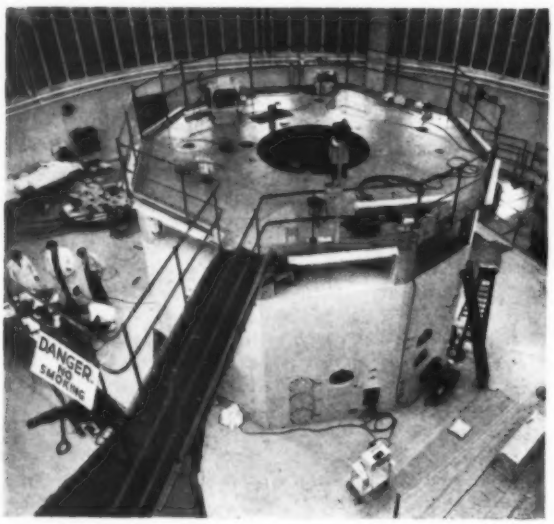
The reactor is permeated with pockets and tubes for conducting experiments, and the wide programme of research to be undertaken ranges from studies in fundamental physics to basic technology. In "engineering pile loops", which will be maintained within the reactor, fuel assemblies for future power-reactor designs will be tested under working conditions, and the neutron intensity available will reduce time required for this work from years, as hitherto, to weeks. The effects of radiation on materials will be investigated with special reference to the alterations which are caused in possible power-reactor coolants, moderators and fuel assemblies. In particular, the reactor will be used to see how displacement of atoms by neutron bombardment affects the physical properties of metals, and the study of increase of creep under irradiation will be an important part of this type of work. All spare space round the reactor core will be packed with cobalt, which will be converted into cobalt-60 of high specific activity for hospital and industrial use.

The core of the reactor is an array of twenty-five vertical boxes each made up into a composite fuel element from ten curved uranium-aluminium alloy plates. The array of boxes forms a rough cylinder about 2 ft deep and 2 ft 9 in. in diameter. The reactor is controlled by moving six cadmium-sheathed "signal arms" into the core between the fuel elements. It is contained in an aluminium tank holding the coolant, heavy water. Exterior to the aluminium tank is a 2-ft reflector of graphite sealed in a helium-filled boral-steel tank; a 4-in. thick thermal-shield of lead cooled with de-ionised water and a 5-ft thick wall of concrete. Ten tons of heavy-water coolant are in use in Dido. From a circuit outside the reactor the coolant is forced upwards through the fuel elements, and is then passed through heat exchangers installed below the reactor. It circulates once every three minutes. The heat is transferred to "ordinary" water which, in turn, is cooled in towers. The heat drop of the coolant in the exchangers is from about 60 to 50°C. Leakage of coolant, which is of American manufacture and costs £20,000 a ton, must not exceed 5 c.c. a day. Above the heavy water is a circulating helium atmosphere to prevent the hydrogen and oxygen produced by the splitting of the heavy water by radiation forming an explosive mixture. The reactor is contained in a gas-tight cylindrical steel building 70 ft × 70 ft. which is capable of holding any radioactive fission products which might be released by a reactor accident (a most unlikely occurrence).

A companion reactor, Pluto, is expected to come into operation in 1957. Dido was officially put into operation by Sir Cyril Hinshelwood, P.R.S., at a ceremony at Harwell on November 21, 1956.



1. *Reactor aluminium tank.* 2. *Heavy-water level.* 3. *Fuel element.* 4. *Vertical experimental hole thimble.* 5. *Control signal arms.* 6. *Experimental hole* 4 × 2 *in.* 7. *Top biological shield.* 8. *Graphite reflector.* 9. *Experimental holes* 12 × 8 *in.* 10. *Lead thermal shield.* 11. *Reactor steel tank.* 12. *Experimental hole entering heavy-water zone.* 13. *Experimental hole entering graphite zone.* 14. *Vertical experimental hole entering graphite zone.* 15. *Concrete biological shield.* 16. *Reactor-supporting structure.* 17. *First floor.* 18. *Thermal column.* 19. *Hollow stanchions communicating with base of reactor.* 20. *10-in. thick steel top plate.* 21. *Duct for experimental services.* 22. *Biological shield casing plates.* 23. *Ion chamber.* 24. *Fine-control rod gearbox.* 25. *Heavy-water outlet pipe.* 26. *Heavy-water storage tank.* 27. *Heavy-water safety dump tank.* 28. *Heavy-water heat exchangers.* 29. *Heavy-water main circulating pump.* 30. *Secondary cooling water piping.*



DIDO during criticality experiments when loaded with the critical amount of fuel.

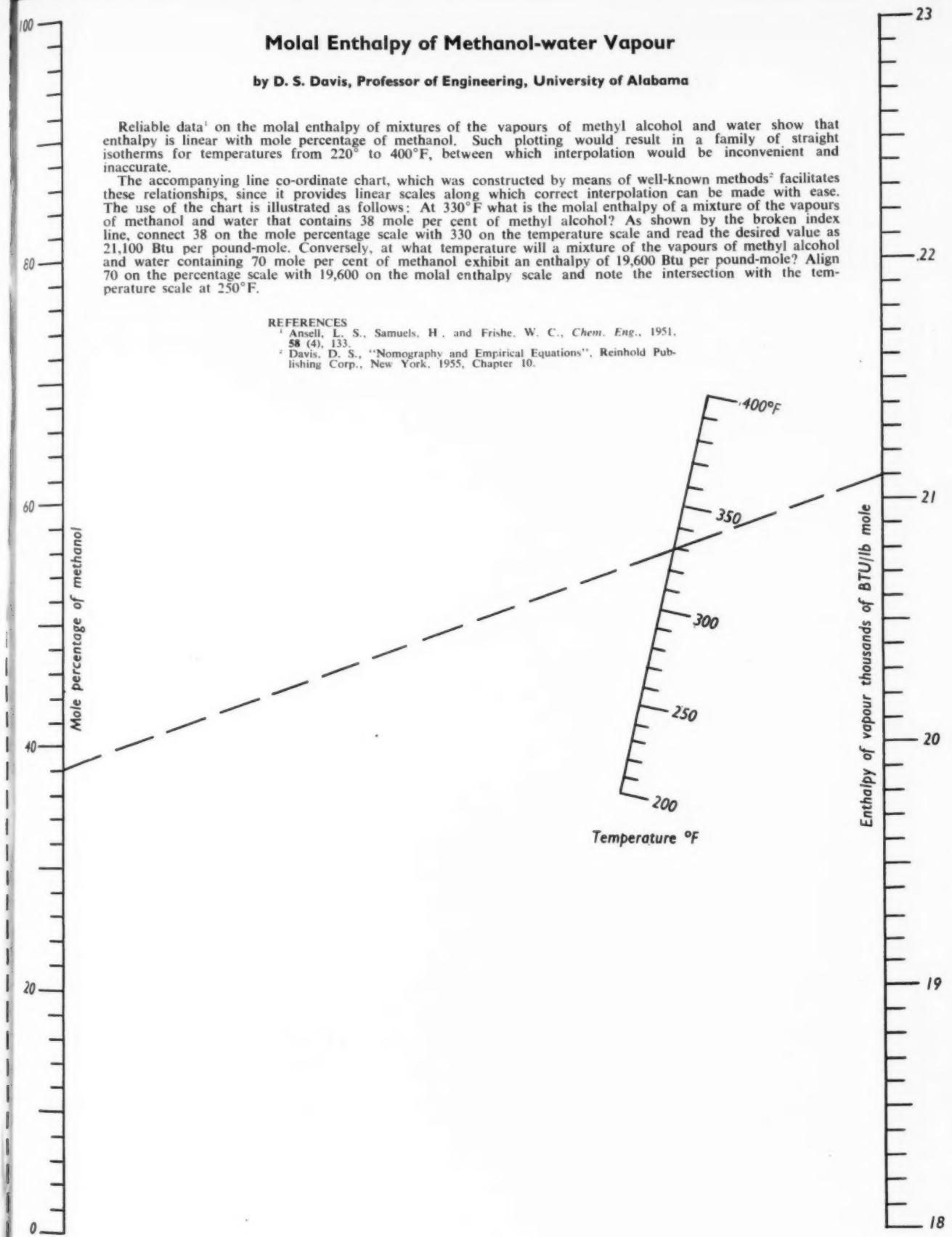
Molal Enthalpy of Methanol-water Vapour

by D. S. Davis, Professor of Engineering, University of Alabama

Reliable data[1] on the molal enthalpy of mixtures of the vapours of methyl alcohol and water show that enthalpy is linear with mole percentage of methanol. Such plotting would result in a family of straight isotherms for temperatures from 220° to 400°F, between which interpolation would be inconvenient and inaccurate.

The accompanying line co-ordinate chart, which was constructed by means of well-known methods[2] facilitates these relationships, since it provides linear scales along which correct interpolation can be made with ease. The use of the chart is illustrated as follows: At 330°F what is the molal enthalpy of a mixture of the vapours of methanol and water that contains 38 mole per cent of methyl alcohol? As shown by the broken index line, connect 38 on the mole percentage scale with 330 on the temperature scale and read the desired value as 21,100 Btu per pound-mole. Conversely, at what temperature will a mixture of the vapours of methyl alcohol and water containing 70 mole per cent of methanol exhibit an enthalpy of 19,600 Btu per pound-mole? Align 70 on the percentage scale with 19,600 on the molal enthalpy scale and note the intersection with the temperature scale at 250°F.

REFERENCES
[1] Ansell, L. S., Samuels, H., and Frishe, W. C., *Chem. Eng.*, 1951, **58** (4), 133.
[2] Davis, D. S., "Nomography and Empirical Equations", Reinhold Publishing Corp., New York, 1955, Chapter 10.



AMERICAN LETTER

U.S. Atomic Power Development

THE industrial revolution growing out of the intensive technologic study of the energy of the atom is growing to significant stature. Many diverse possibilities are casting their influence over our entire economy, but power generation is receiving the greatest attention. In the interval between the start of the world's first power reactor at Calder Hall and the operation of the first American plant at Shippingport, Pennsylvania, it is appropriate to review the status of the peaceful use of atomic energy in the U.S.A.

During the years immediately after the war, the use of radioactive tracers and the use of radiation techniques gave direction to the peaceful application of atomic energy. Atomic power studies were largely in the hands of the Atomic Energy Commission, and this work led to the atom-powered submarine, the proposed merchant vessel and government-sponsored small-power projects. There was considerable discussion among the power utilities, but action was slow. Problems of classified information, available source materials, engineering background and the apparent costliness of atomic power relative to other sources of power made for a slow start. Technical progress, the U.S. atomic energy act of 1954, and diversification of the subject into several government agencies resolved many of these problems. Now, power development is well under way. Substantial investments are being made by the industry and the types of installations involved are widely diversified.

The Government's experimental programme for civilian atomic power involves an expenditure of a quarter billion dollars, of which less than 10% is contributed by industry. The units include:

(1) Los Alamos power reactor experiment, Los Alamos, New Mexico. (2) Experimental boiling water reactor (5000 kW), Argonne National Laboratory, Lemont, Illinois. (3) Homogeneous reactor experiment (2000 kW), Oak Ridge, Tennessee. (4) Sodium reactor experiment (7500 kW), North American Aviation for Atomic Energy Commission, Santa Susana, California. (5) Organic-moderated reactor experiment, North American Aviation for A.E.C., National Reactor Testing Station. (6) Pressurised-water reactor (60,000 kW), Westinghouse and Duquesne for A.E.C., Shippingport, Pa. (7) Experimental breeder reactor (15,000 kW), Argonne National Laboratory, National Reactor Testing Station. (8) Molten plutonium reactor experiment, Los Alamos, New Mexico. (9) Liquid-metal-fuelled reactor (contractor not selected). (10) Gas-cooled reactor (contractor not selected).

The first five of these commenced operation in 1956; the large unit at Shippingport is due to operate in 1957, the Argonne breeder reactor in 1958 and the molten plutonium reactor in 1959.

Then there is a power demonstration programme scheduled in two rounds. The cost of about $170 million is supported one-third by Government and two-thirds by industry. The programme includes the following items:

First round (1959-60 operation). (1) Pressurised-water reactor (134,000 kW), Kankee Atomic Electric Co., Rowe, Mass. (2) Fast breeder reactor (100,000 kW), Power Reactor Development Co., (Detroit Edison *et al.*), Monroe, Michigan. (3) Sodium-graphite reactor (75,000 kW), Consumers Public Power District, Beatrice, Nebraska.

Second round (operation 1960 onwards). (1) Boiling-water reactor (22,000 kW), Rural Cooperative Power Association, Elk River, Minnesota. (2) Pressurised-water reactor (2000 kW), University of Florida, Gainesville, Florida. (3) Organic-moderated reactor (12,500 kW), City of Piqua, Piqua, Ohio. (4) Aqueous homogeneous reactor (10,000 kW), Wolverine Electric Cooperative, Hersey, Michigan. (5) Sodium-cooled, heavy-water moderated (10,000 kW), Chuqach Elect. Association, Nuclear Development Corporation of America, Anchorage, Alaska. (6) Liquid-metal-fuelled reactor (25,000-40,000 kW), City of Orlando, Orlando, Florida. (7) Gas cooled reactor (15,000 kW), City of Holyoke, Holyoke, Massachusetts.

The independent industrial programme presently contemplates an expenditure in excess of $200 million, of which $145 million is committed at three locations for completion by 1962. No Government financing is involved. The major industrial projects are as follows:

(1) Boiling-water reactor (180,000 kW), Commonwealth Edison Co., Dresden, Illinois. (2) Pressurised-water reactor (150,000 kW), Consolidated Edison Co., Indian Point, New York. (3) Aqueous homogeneous reactor (150,000 kW), Pennsylvania Power & Light Co., Eastern, Pennsylvania.

A few points about the reactor types may be noted.

(a) Pressurised-water-fuel rods are cooled by water at 2000 psi and 500°F water pumped through heat exchanger to boil water for a turbo-generator. Corrosion- and leak-resistance are feasible but costly.

(b) Boiling-water-fuel elements are water-moderated, and water is boiled directly to make steam for the generator. It offers the advantage of lower pressure and elimination of heat-transfer equipment, but involves a special system of controls.

(c) Sodium-graphite. A graphite moderator is used; liquid sodium is the coolant, which yields its heat through a heat exchanger. It is presently expensive due to a double heat exchanger and a complex core.

(d) Fast breeder. A sodium-cooled system using no moderator, it has a blanket of U-238 to be converted to plutonium.

(e) Organic-moderated. Organic compounds (e.g., diphenyl, terphenyl), having low induced radioactivity, low corrosion of fuel elements and lower pressures than water at high temperatures offer possibilities as moderator coolants.

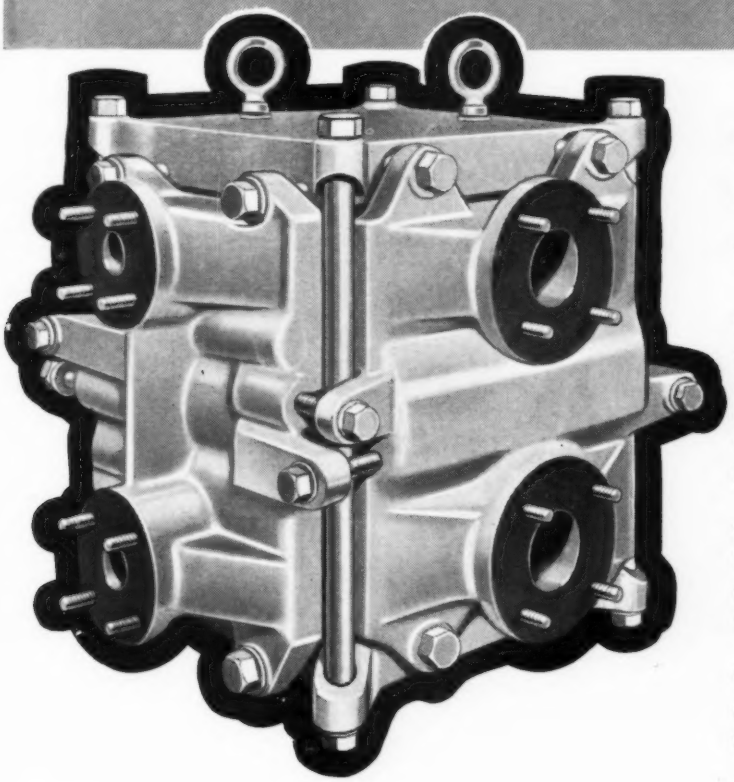
(f) Aqueous homogeneous-fuel, moderator, and coolant in a single solution simplifies some phases of the problem.

(g) Liquid metal. With graphite as a moderator, bismuth-uranium melt generates and transfers heat.

(h) Gas-cooled. At gas temperatures of 1400°F or better, this is an effective means of cooling fuel and boiling water. Its possibilities are better if the gas can be used to drive a turbine directly.

At the end of last October the Battelle Memorial Institute announced that their million-watt research reactor had started up. This will be used for research into the chemistry of petroleum, sterilisation of pharmaceutical products, preservation of agricultural goods, and improvement and development of chemical, plastic, ceramic and metallic products. Through this type of research, another side of "atoms-for-peace" will be revealed.

Heat exchanger standardisation



Can your heat exchangers be readily converted from one duty to another?

Unsuitably spaced shell baffles, limited pass arrangements, corrosion, space requirements etc., all seriously restrict the flexibility of tube and shell heat exchangers. Consider the advantages of the graphite block heat exchanger from this point of view:

★ Standard sub-assembly, corrosion proof on both sides and suitable for heating, cooling and condensing most fluids and vapours, using steam, water or brine on either side.

★ Pass arrangements varying from 1 to 16 are obtainable on either or both sides merely by substitution of headers.

★ Exceptionally compact, can be installed in very confined space and requires no special supporting structure. Easily cleaned *in situ* either chemically or by brushing.

DELANIUM
CARBON & GRAPHITE

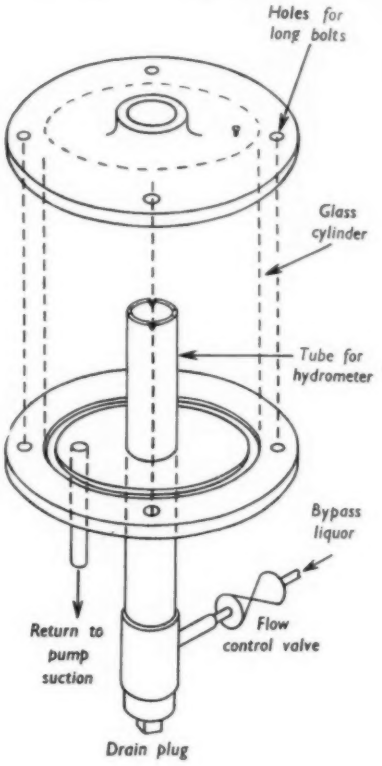
POWELL DUFFRYN CARBON PRODUCTS LTD

Springfield Road, Hayes, Middlesex. Telephone: Hayes 3994-8

PROCESS ENGINEER'S NOTEBOOK

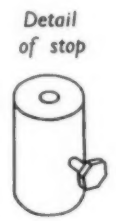
Home-made Density Indicator

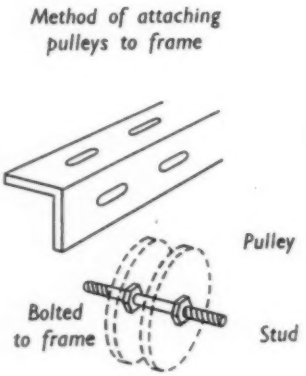
A SIMPLE indicator is detailed here which should prove useful in processes where the composition of product is denoted by density. Such would be the case in a batch-absorption process wherein the liquor is recirculated around the absorption column until a certain concentration of absorbed material is reached as is indicated by density. In such cases, a bleed of the liquor to the column may be fed continuously to the density-indicating instrument and returned to the main stream at some suitable point on the suction side of the pump. A simple and inexpensive density indicator, employing an ordinary float-type hydrometer, is shown in the accompanying sketch. It consists of an open-ended tube squared at its end with vee notches cut into it. The hydrometer is placed inside this tube and is floated in the liquid overflowing across the notches. The notched tube, as shown, is fixed either by screwing or welding it into a lower flange. This is drilled to take long bolts and also for the discharge connection for returning the fluid to the main stream. The entire assembly, consisting of glass cylinder and upper flange, is bolted together in the manner shown. The upper flange carries a plug which can be unscrewed for removal or rotation of the hydrometer. The height of the tube relative to the length of the glass cylinder is of importance, as the upper end of the hydrometer should at all times be within reach through the upper flange opening. A screwed socket at the hydrometer end of the tube can be used if greater flexibility is desired. This should have rectangular-shaped notches for ease of adjustment.

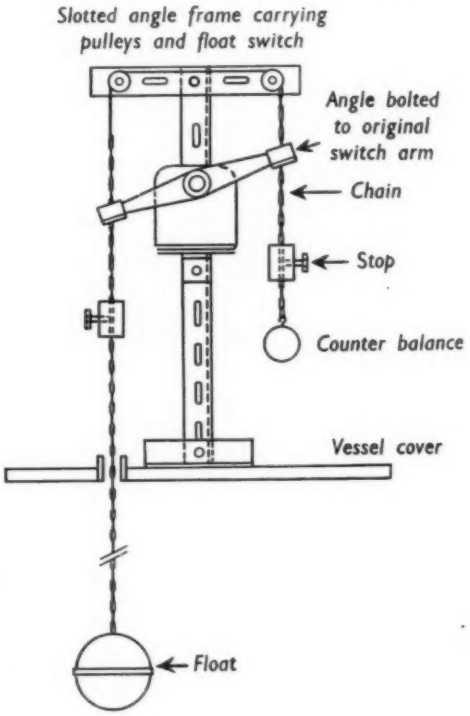


Improved Float Control

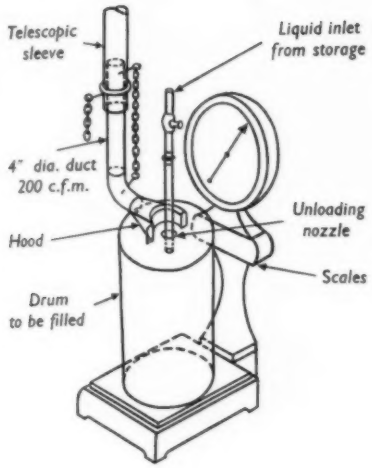
THE ACCOMPANYING diagram shows an arrangement of a float switch for controlling the level of contents inside a tank which has advantages over the type of float switch connected by means of a rod to the float. One disadvantage of the latter is that the rod often has a tendency to stick, thereby upsetting the whole process of control or level indication. The diagram shows an improved method of using an existing switch in which the rod is replaced by a chain. The chain, which is less prone to stick than the rod it replaces, is carried on two pulleys mounted on a suitable framework. The switch arm may require modifying to allow the chain to pass through its ends. As can be seen from the diagram, the method used was to drill two small pieces of angle to allow the chain to move through comfortably, the pieces being bolted to the arm through which, previously, the rod and counterweight were attached. Two clamps were made from aluminium round bar to thread the chain, and these were fitted below the switch arm. The clamps may be adjusted to give operation of the switch over a wide range of float movement. Testing of the switch or float is readily carried out by releasing the chain from the pulleys and manipulating the switch.





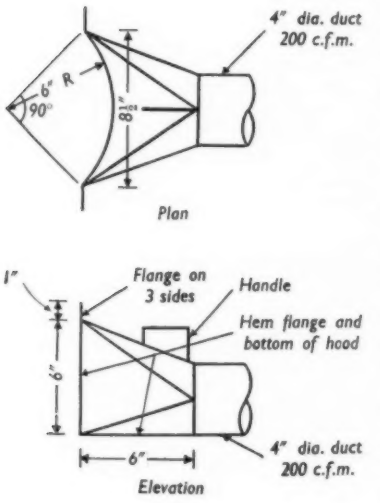


Fume Extraction Device for Weighing Operations



THE DIAGRAM given above shows a fume-extraction device which is suitable for use when unpleasant or toxic liquids have to be weighed off into drums. As can be seen from the illustration, it consists of a small hood shrouding the opening to the drum. This hood can be raised or lowered into the desired position, depending upon the height of the drum—a feature which also comes into play when a drum has to be removed from, or placed on, the scales.

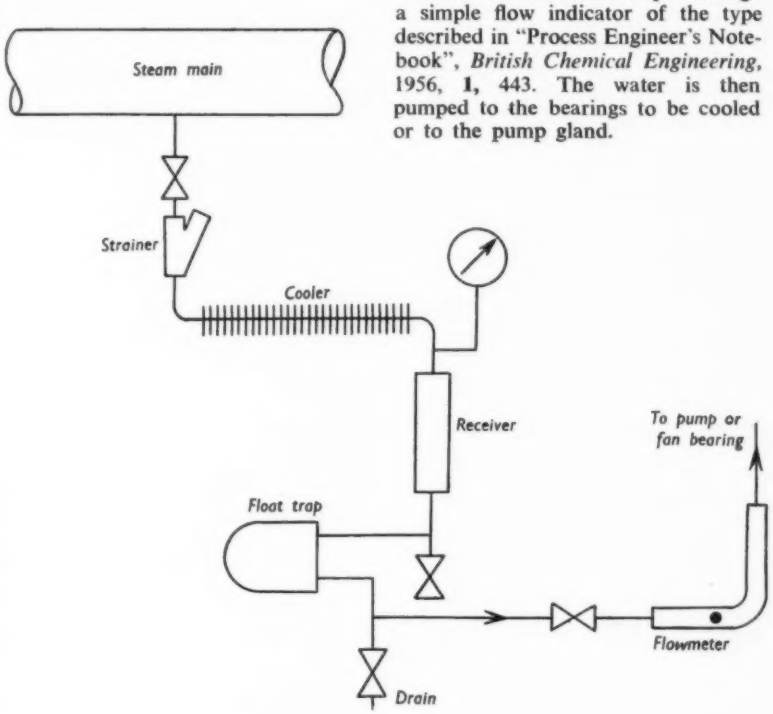
Constructional details of the hood are given in the lower illustration for both plan and elevation.



Condensate as a Lubricant for Pump Glands

THIS IDEA details the use of condensate from steam mains as a source of water for lubricating the glands of a centrifugal or other type rotating pump, or for cooling bearings of small-sized fans handling hot gases. In the latter case, really cold water should be avoided when possible.

The main apparatus consists of a length of gilled tubing which precedes a receptacle for cooled condensate. The latter is discharged continuously by means of a float trap through a simple flow indicator of the type described in "Process Engineer's Notebook", *British Chemical Engineering*, 1956, **1**, 443. The water is then pumped to the bearings to be cooled or to the pump gland.



pH Instruments as Safety Devices

AN INTERESTING use for a pH indicator was noted recently at the N.C.B. plant at Wingerworth, Chesterfield. The detecting cells of the instruments are situated in the pipe-lines conveying cooling water from the reaction acid and denitrated acid coolers of the Kachkaroff sulphuric acid plant. The purpose of the instruments is to give an alarm of acid leakage at any of the coolers, or to enable the offending cooler to be singled out for repair, and to protect the remainder of the cooling water system, including the pumps and towers.

It can be appreciated that any leakage of acid into the equipment would cause extensive and costly damage out of all proportion to the cost of the pH alarm indicator.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

Book Reviews

Ion Exchange Technology

Edited by F. C. Nachod and J. Schubert
Academic Press Inc., New York, 1956.
660 pp., $15

SEVERAL text-books on ion exchange have now appeared, but this is the first to deal with its technological and engineering aspects. It is written in the form of 20 chapters by experts in their respective subjects and it gives an excellent presentation of the field, beginning with a discussion of the ion-exchange materials, some of the fundamentals underlying their action, and the design and construction of ion-exchange plant and equipment. The rest of the book deals with various industrial applications, both actual and potential, to water treatment, metal recovery, acid-base catalysis, radiochemistry, and to some organic-biological processes. Economic considerations are also dealt with, and these help to put the whole into perspective.

The layout is excellent, each chapter being divided by clear headings and sub-headings, and there is a unanimity of style and presentation that is rare in books written by a number of separate contributors.

In a field that is expanding as rapidly as that of ion exchange, there is a great likelihood of a book being out of date by the time it appears in print. This is not the case with the present book. Its topicality can be judged by the fact that it contains a description of the ion-exchange process for the recovery and concentration of uranium (now practised on a very large scale), a subject from which the official veil of secrecy was lifted only in August of last year. This topicality is a credit alike to editors, authors and publishers. If any criticism can be made, it is that the references are inclined to be insular, and American work tends to be quoted in preference to similar work performed outside the U.S.A.

With one exception, the book is based on American practice and this is not necessarily always the same as British practice. The differences, however, are generally in detail only, and there is sufficient in common to make the book extremely valuable to all who are interested in the large-scale application of ion exchange, whether in designing ion-exchange processes, or in using them. To these, the book is highly recommended.

T.R.E.K.

Nuclear Energy in Industry

by J. G. Crowther
George Newnes Ltd., 1956. 168 pp., 17s. 6d.

ALTHOUGH this book is written primarily for the scientifically-minded members of the public, the laity, whether from among the general public or technologists, who wish to improve their acquaintance with the quickly-growing subject of nuclear power should find much of use within its easily-read pages. An outcome of the author's attending the International Conference on the Peaceful Uses of Atomic Energy in Geneva in 1955, the book is written in a clear style and with infective enthusiasm. The author traces the history of nuclear research and of the harnessing of nuclear energy to industrial purposes in Britain, America, Russia and other countries. He discusses the significance to industry and society of this potentially great source of power. The new technique of nuclear industry will influence thinking in the old industries, he suggests, and therefore it is to the advantage of all industrialists to familiarise themselves with its ideas so that they can adopt those which may improve their own processes, no matter how remote they seem at the moment from the nuclear industry. Much of the text is devoted to a description of nuclear power stations that were being built or planned at the time of writing (including Calder Hall) and to the attendant new problems in metallurgy and engineering. The view is put forward that in the matter of big accelerators Britain is "far behind"—and it is hoped only temporarily so—both the U.S.A. and the U.S.S.R. The volume is amply illustrated with, on the whole, well-chosen pictures.

G.D.

Chemical Market Research in Practice

Edited by R. E. Chaddock
Chapman & Hall Ltd., London, 1956.
196 pp., 24s.

THE material on which this book is based was prepared by twenty-two experts, members of the U.S.A. organisation the Chemical Market Research Association. The subject-matter was originally presented as lectures at the Case Institute of Technology and university extension lectures at Delaware. The book has only a 50% value for readers in Great Britain because of the proportion of it which deals with specifically American practice, particularly in the shape of the behaviour of certain industries and the availability of sources of information dealing with them. In the more general half of the book, matters are discussed which are of concern to those engaged in attempting to forecast markets in any part of the world. There are chapters which discuss in simple terms the values and functions of market research; how to set about a market survey; the personal requirements of a worker in market research; the method of reporting results. This is the sort of stuff which should be within the comprehension of the normal sales manager.

High-temperature Technology

Edited by I. E. Campbell
Chapman & Hall Ltd., London, 1956.
526 pp., 120s.

APPROXIMATELY half of this monograph is devoted to summarising the known facts about materials suitable for use at temperatures of 1500°C and beyond. Such are the oxides, carbides, nitrides, borides and silicides of a number of elements, together with carbon and graphite and certain of the cermets such as refractory oxides or carbides bonded with suitable metals. The other half of the book is a statement of the methods of achieving high temperatures and measuring them and the properties of substances subjected to them.

Fluid Flow in Practice

Edited by J. R. Caddell
Chapman & Hall Ltd., London, 1956.
119 pp., 24s.

THIS book is comprised of seven contributions originally delivered to a symposium sponsored by the University of Pennsylvania and a section of the American Institute of Chemical Engineers. It includes an introductory review of the basic relationships which is delivered at about the level of Higher National Certificate, and is finished by a speculation on the trends in research by A. S. Foust. This latter contribution is interesting by virtue of the humility displayed before the problems of real plant, particularly in respect of two-phase systems. The other five chapters are of the "how to do it" type giving simple comments on the methods of choosing pipe arrangements, specifying valves, pumps and flowmeters, and the maintenance of equipment. These practical chapters are likely to be of value in assembling material for the training of apprentices or lecturing to skilled operators. They vary in value, the article on pump choice, by C. J. B. Mitchell, being perhaps the best.

CHAPMAN & HALL

★ *New Books* ★

HYDROGEN IONS

Their Determination and Importance in Pure and Industrial Chemistry

by

Hubert T. S. Britton

D.Sc. (London), D.I.C., F.R.I.C.

VOLUME TWO — FOURTH EDITION REVISED & ENLARGED

Size: 8¼" × 5¼" *508 pages* *Illustrated* *75s. net*

As in the case of the first volume, the revisions to the text have been extensive. While that volume dealt mainly with the theory and methods of determining hydrogen-ion concentration or activity, this second volume examines the part played by hydrogen ions in chemistry and its numerous technical processes in industry.

BIOLOGICAL TREATMENT OF SEWAGE AND INDUSTRIAL WASTES

Volume I — Aerobic Oxidation

Edited by

Joseph McCabe & W. W. Eckenfelder Jr.

Size: 9¼" × 6" *400 pages* *Illustrated* *80s. net*

This book records the proceedings of the first Conference on Biological Waste Treatment held at Manhattan College, New York in 1955. Thirty-three papers contributed by recognised authorities and arranged in logical sequence, review the whole subject of bio-oxidation and and present the latest trends in research, development plant design.

THE CONDENSED CHEMICAL DICTIONARY

Completely Revised and Enlarged

by

Arthur & Elizabeth Rose

FIFTH EDITION

Size: 9" × 6" *1200 pages* *100s. net*

With over 30,000 entries in the present edition, this is probably the largest and most complete chemical dictionary available, both in the number and kind of entries, as well as in the extent of essential information given under each. Its value as a source of quick, accurate data on chemicals, chemical terminology, trade-name products and related substances, cannot be over-estimated.

THE ENCYCLOPAEDIA OF CHEMISTRY

Edited by

George L. Clark

(Research Professor, University of Illinois)

Size: 10" × 7" *1100 pages* *156s. net*

This monumental American work has taken several years to prepare. Over 800 articles, ranging in length from 300 to about 4000 words have been provided by more than 500 contributors, each one a recognised expert in his field. This new reference book is a complete, authoritative survey of chemical science. (Ready March 1957)

37 ESSEX STREET, LONDON, W.C.2

Principles of Physical Metallurgy

and

Alloy Series in Physical Metallurgy

both by MORTON C. SMITH

Each Volume Med. 8vo. Illustrated 50*s*.

Electrostatic Precipitation in Theory and Practice

by H. E. ROSE and A. J. WOOD

Cr. 8vo. 168 pages 17*s*. 6*d*.

The Measurement of Particle Size in Very Fine Powders

by H. E. ROSE, Ph.D., M.Sc.

Ex. Cr. 8vo. Illustrated 9*s*.

Grignard Reactions of Nonmetallic Substances

by M. S. KHARASCH and OTTO REINMUTH

Roy. 8vo. 1384 pages 135*s*.

"Its value to chemists is nothing short of tremendous." (*J. Roy. Inst. Chem.*)

Advanced Organic Chemistry

by E. E. ROYALS

Roy. 8vo. 948 pages 68*s*.

The Petroleum Acids and Bases

by H. L. LOCHTE and E. R. LITTMAN

Demy 8vo. 360 pages 50*s*.

Chemical Engineering Materials

by F. RUMFORD, Ph.D., B.Sc., M.I.Chem.E.

Demy 8vo. 350 pages 32*s*. 6*d*. net.

Second Edition Ready January

Chemical Engineering Operations

An Introduction to the Study of Chemical Plant

by F. RUMFORD, Ph.D., B.Sc., M.I.Chem.E.

Demy 8vo. 376 pages Illustrated 32*s*. 6*d*.

CONSTABLE & CO. LTD.

10 ORANGE STREET, LONDON, W.C.2

PLANT EQUIPMENT NEWS

Protection Against Rocket Fuels

In collaboration with members of the aircraft industry, R.F.D. have produced special clothing for the protection of operatives engaged in the use of high test peroxide (HTP) and other rocket fuels. The fabric is constructed in Terylene polyester, proofed on both sides with high-grade PVC. Both textile and proofing are resistant to the action of HTP. **R.F.D. Co. Ltd., Industrial Safety Division, Godalming, Surrey.**

BCE 690 for further information

An Area Meter

An area meter for measuring rates of flow has been developed by Bailey Meters. It consists essentially of a transmitter which is installed in the pipe-line like a valve, and an electronic-type receiver which may be located at a distance from the transmitter. The principle of operation is that, as the differential pressure remains substantially constant across variable area metering ports, the area of the ports must be directly proportional to the rate of flow. The ports are rectangular in shape and their area varies in proportion to the height of the metering plug. The differential pressure across this plug is counterbalanced by either a calibrating weight or a spring. Ambient temperatures as high as 150°F do not interfere with the instrument's operation. Liquids at temperatures under 200°F may be measured by standard transmitters, but for higher temperatures modifications are required. **Bailey Meters & Controls Ltd., 153 Moorgate, London, E.C.2.**

BCE 691 for further information

Photoelectric Temperature Control

A new photoelectric temperature-control unit, type PR.5, has been introduced by Elcontrol. It makes use of the response of a photocell to varying light intensity to provide a relay operation to an electric heating element at different colour temperatures. It is designed to switch the heating current on when the temperature of the workpiece drops below the desired figure, and to switch it off when the temperature rises above it, the differential being as little as 5% of the higher temperature. A modified version of the company's photoelectric temperature limit switch, which works on a similar principle, has also been made available. **Elcontrol Ltd., 10 Wyndham Place, London, W.1.**

BCE 692 for further information

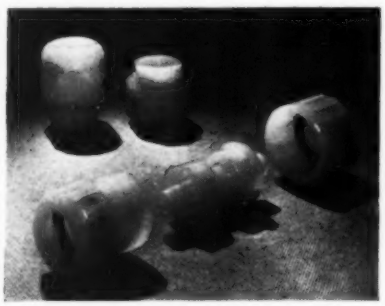
Diaphragm Control Valves

A range of acid-resisting diaphragm control valves having a Vulcathene body is available from Folkard. The body section is a complete moulding of the plastic, and the bonnet assembly is of grey cast-iron wheel-operated and with a non-rising spindle operation. The valves are made for the following pipe-sizes: ½ in., ¾ in., 1 in., 1½ in. and 2 in.: they are available with a variety of grades of flexible diaphragms. **J. S. & F. Folkard Ltd., Rectory Lane, Edgware, Middlesex.**

BCE 693 for further information

New Hose Coupling

A new nylon hose coupling is being made available in Britain by Bowden (Engineers) Ltd. Among the advantages claimed for it are that it can accept hoses of widely differing wall thicknesses (or outside diameters); connection takes only a few seconds; it has no parts to be mislaid or damaged; and no special tools are required for attachment. The coupling



is available for hoses of up to 1-in. inside diameter, to withstand pressures of up to 200 lb./sq. in. **Bowden (Engineers) Ltd., Willesden Junction, London, N.W.10.**

BCE 694 for further information

Vacuum Chlorinator

The BA-678 chlorinator by Wallace & Tiernan has been designed for industrial plants and other works which require a simple chlorinator of wide capacity to treat a continuous or interrupted flow. It is operated under vacuum and possesses a diaphragm chlorine pressure-reducing valve. The vacuum relief eliminates the possibility of back flow into the chlorine inlet connections. The meter of the chlorinator maintains a set feed rate within 4% on all flows in its calibrated range under normal operating variations. **Wallace & Tiernan Ltd., Power Road, London, W.4.**

BCE 695 for further information

An Adaptable Bung-wrench

A new universal bung-wrench has been added to the range of Telcon tools. It will open fifteen different designs of bung. The tool has "non-sparking properties" and, the makers say, may be

used safely in explosive atmospheres. **Beryllium & Copper Alloys (Safety Tools) Ltd., 47 Victoria Street, London, S.W.1.**

BCE 696 for further information

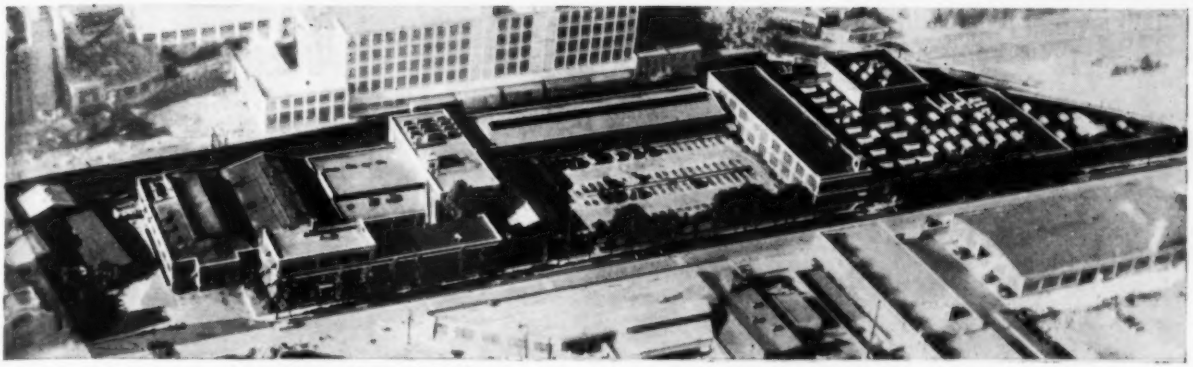
Welding Plastic Tubes

A tool for joining vulcathene pipes and fittings has been made available by Folkard. In use it is heated gently with a blowpipe and the pipe and the fitting to which it is to be joined are then manipulated over it. The touching surfaces of pipe and fitting are melted and the materials are amalgamated. An electrically heated variation of the tool is being made. **J. S. & F. Folkard Ltd., Rectory Lane, Edgware, Middlesex**

BCE 697 for further information

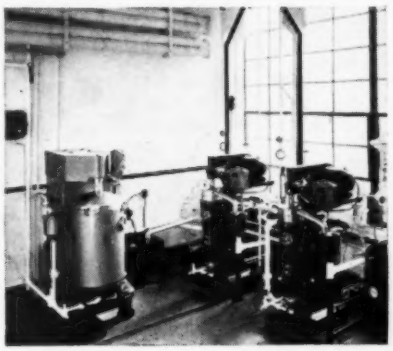
Plastic Pipes for the Oil Industry

DuPont are manufacturing primarily for the oil industry three new thermoplastic pipes, under the trade name of Durapipe Z, K or N. The materials of which they are made are strong and light in weight and resist corrosion. The final products are in light, normal and heavy gauges with outside diameters conforming to British Standard 1600 (1950), American Petroleum Institute Standard A.P.I. 5-L, and in keeping with British Standard 1387. All of the pipes are normally fabricated in 20 or 25-ft lengths, and Durapipe K and N may be jointed with solvent or adhesive cement applied by brush. Each grade of Dura-

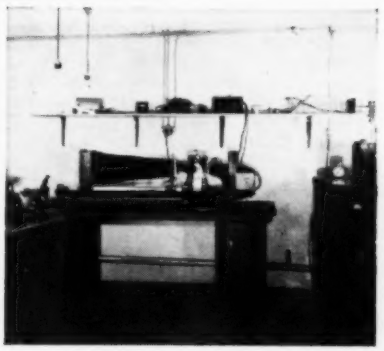


An aerial view of one of the Sharples works—just one of the plants throughout the world.

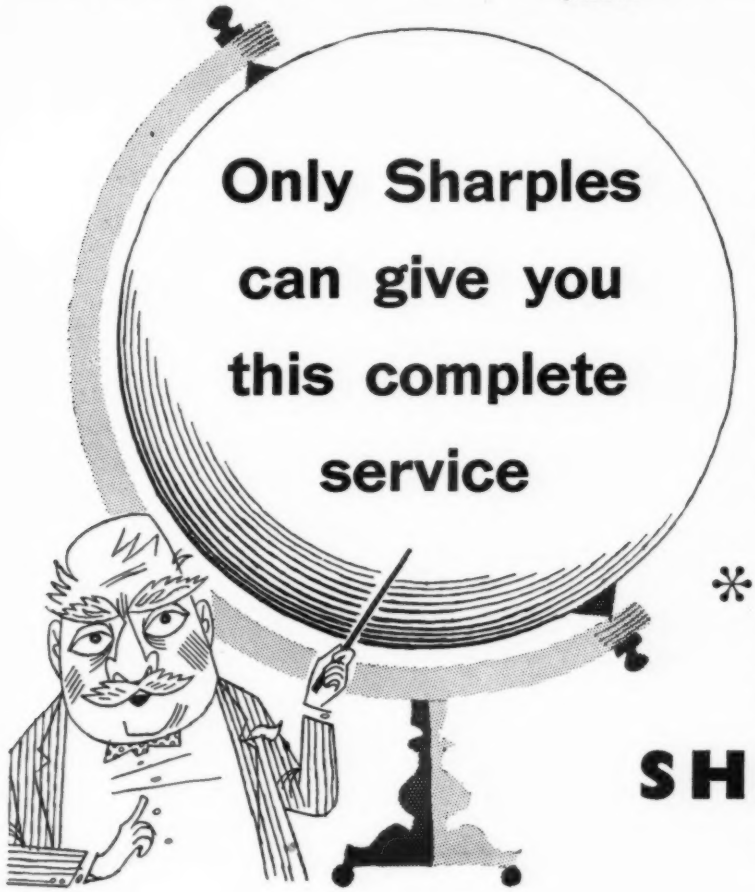
The light machine shop in the Lightpill plant. An entirely new Sharples factory is nearing completion at Camberley, Surrey.



Full-size development plant for a Sharples process. This is regularly in operation adding to Sharples' extensive knowledge of separation problems.



An X-ray Diffraction Camera in one of the Sharples laboratories. Every modern research tool which can help to solve separation problems is at work in Sharples laboratories.



YOU DON'T just buy plant from Sharples, you invest in a service—the most complete of its kind in the world. You benefit from research and development facilities, including full-size development plants, in Sharples establishments in many countries. The technical advice you get is based on an enormous experience of separation technology. This knowledge may be worth more to you than money itself. When you order Sharples plant, you have the benefit of a world-wide manufacturing organisation which pools its skill and knowledge. And wherever you may be you can be sure of tip-top maintenance and spare parts service.

* *Sharples are established in the United Kingdom, Holland, America, Canada, Sweden, Norway, Spain, Italy, Finland, France, Australia, S. America, Japan, Germany, Mexico, New Zealand, S. Africa, Belgium, Portugal, the Middle East, etc.*

Write for Bulletin No. 2956S. "A guide to the selection of continuous centrifuges in the Chemical Industry."

SHARPLES

Sharples Centrifuges Ltd., Woodchester, Stroud, Gloucestershire. *Amberley* 2251

PLANT EQUIPMENT NEWS

pipe is suited to different conditions and performance charts are available to aid selection. **Richard E. DuPont Ltd., 56 Kingsway, London, W.C.2.**

BCE 698 for further information

Rotary Air Filter

Special features claimed for the new Vokes SC rotary screen and air filter element include automatic operation, absence of carry-through of the oil coating and constant cleansing. Each filter panel of the assembly is supported on a pair of endless chains so that it always presents the same face to the incoming air. As a filter panel enters the oil tank, it is caused to oscillate, thus ensuring a powerful cleansing flow of oil through the air passages. The endless chains are driven by a pneumatic plunger. **Vokes Ltd., Guildford, Surrey.**

BCE 699 for further information

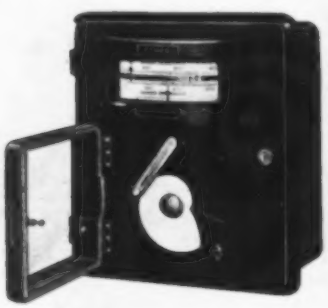
Control of Bunker Filling

Smail, Sons have introduced to Britain the Maihak bunker-level indicator for the automatic control of bunker filling and conveying installations. The equipment includes a motor-driven paddle fitted to the bunker. When the level of material in the bunker reaches that of the indicator, the movement of the paddle is stopped, and once the level of the material falls below the tip of the paddle, the paddle is caused to rotate again. The equipment is suitable for use with materials such as grain, soap flakes, dried milk and cement. **Smail, Sons & Co. Ltd., Glasgow, C.2.**

BCE 700 for further information

Transistor Temperature-controller

The new Transitrol programme temperature-controller, type 994, is a direct deflection instrument designed to indicate and control temperature over a wide range. Although it can be applied to any process where a signal of change can be converted into a direct



current or voltage, it is used mainly for controlling the heating and cooling cycle of a furnace load. It enables the load to be heated automatically at a predetermined rate, held at the soaking temperature for a given time and then cooled as required. The instrument consists of two parts—the indicating temperature-control unit and the time/temperature programme unit. The temperature-control unit operates on a principle which utilises a transistor and, in consequence, the need for thermionic valves, magnetic amplifiers and oscillator circuits has been eliminated. It embodies few moving parts. **Ether Ltd., Tyburn Road, Erdington, Birminham, 24.**

BCE 701 for further information

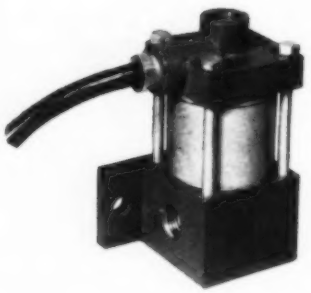
Metallic Lead Paint

Bitulac metallic lead paint, originally evolved as a one-coat preservative for exposed metal work, is now recommended by the makers as a priming coat to replace red lead. With the passage of time the paint becomes almost alloyed to the metal which it covers, it is claimed, and is resistant to weathering and to the action of sea-water. **Bitulac Ltd., Collingwood Buildings, Newcastle upon Tyne, 1.**

BCE 702 for further information

Solenoid-operated Pilot Valves

Three new solenoid-operated pilot



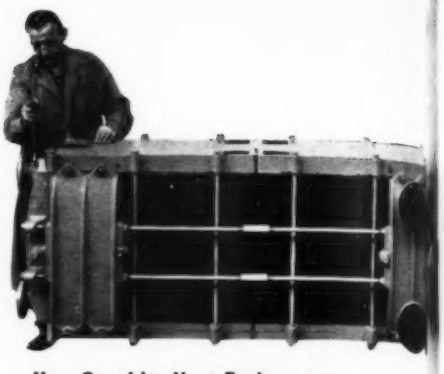
valves have been added to the range of pneumatic and hydraulic equipment manufactured by the Pneumatics Division of Baldwin Instruments. The three valves are made from the basic components of the Type V7/11 solenoid valve, but have different maximum working bores and pressures. These are as follows respectively: $\frac{1}{16}$ in., and 250 psi; $\frac{1}{8}$ in., and 80 psi; $\frac{3}{16}$ in., and 15 psi. **Baldwin Instrument Co. Ltd., Brooklands Works, Dartford, Kent.**

BCE 703 for further information

Chemical Proportioning Gear

A new design of chemical proportioning gear is being made by Bell Bros. It detects a varying differential in flow, and, by the use of a cam-plate, conveys the changes to a variable-speed gear which controls a dosage pump. The equipment is suitable for adding any liquid to water with a flow rate varying in the range 5 to 1. **Bell Bros. (Manchester 1927) Ltd., Calder Iron Works, Denton, Manchester.**

BCE 704 for further information



New Graphite Heat Exchangers

Powell Duffryn have developed a new range of three large rectangular graphite-block heat exchangers. They have effective surface areas of respectively 100, 150 and 200 sq. ft and tube or hole diameters of $\frac{3}{4}$ in. and their design is basically that of the company's Delanium cubic heat-exchanger. Multiple-pass arrangements of up to sixteen passes on either side are available to suit the flow rates of both liquors and to ensure minimum pressure drop. **Powell Duffryn Ltd., 8 Great Tower Street, London, E.C.3.**

BCE 705 for further information

High-vacuum Pumps

The Heraeus high-vacuum Roots pump for vacuum metallurgical-technology is a purely mechanical pump without any valves. It is equipped with two figure-eight-shaped rotors which rotate in opposite directions and are synchronised by a pair of gear wheels. By accurate shaping of the rotors, sufficiently close tolerances are obtained to allow the pump to operate at very low vacuum efficiently. There is no friction, the makers state, between the rotors or between the rotors and the pump body. High-vacuum pumping units are available in the pressure range of between 100 microns and a few millimeters of mercury. **Fleischmann (London), Ltd., 16 Northumberland Avenue, London, W.C.2.**

BCE 706 for further information

Collapsible Containers

Spesco Developments have purchased the British rights of a process for the manufacture of polythene containers made partly of thin film and partly of heavy mouldings. The containers will be collapsible and light—qualities that will make for easy storage empty—and they will be manufactured, where necessary, to specific requirements for various trades and industries. **Spesco Developments Ltd., 195 Uxbridge Road, Hampton Hill, Middlesex.**

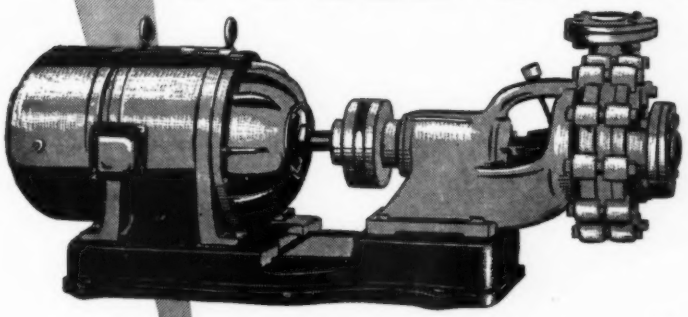
BCE 707 for further information

Centrifugal Fan Units

A new range of extractor and blower centrifugal fans is available from Bellanger. Casings are constructed from heavy-gauge steel plates bolted to the side angles of the pedestals to allow the discharge to be swivelled to eight positions. The runners are fully shrouded

BCE 646 for further information

PUMPS FOR THE CHEMICAL INDUSTRY



TYPE DZT

For flooded suction duties over a wide range of applications incorporating our own corrosion resistant alloys.

AGENTS THROUGHOUT THE WORLD

BRITISH LABOUR PUMP CO. LTD.

BRITISH LABOUR PUMP CO. LTD., BLUNDELL ST. LONDON, N.7

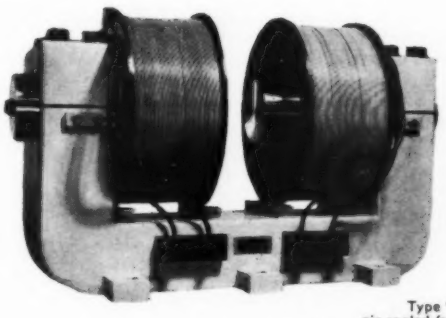
Telephone: NORth 6601-4

SCIENTIFIC

NEWPORT INSTRUMENTS

MOBILE

High Performance ELECTROMAGNETS



Type 'A'
air cooled (to Clarendon Laboratory design) 27" long x 12" wide x 17" high, net weight 5½ cwts.

Precision built for basic research

Suitable for use in Nuclear resonance and induction measurements, determination of magnetic susceptibility and microwave spectroscopy.

Magnets available up to 35000 gauss—Stabilisers and power packs available for all types.

Write for full specification and performance curves.

NEWPORT INSTRUMENTS (SCIENTIFIC & MOBILE) LTD

NEWPORT PAGNELL · BUCKS · ENGLAND

Telephone: Newport Pagnell 401/2

BCE 647 for further information

PLANT EQUIPMENT NEWS

and are of the backward-blade type, and the units are fitted with induction-type motors rated at ¼ h.p. for continuous use. A more powerful model, giving about double the output, is also available. The units are suitable for use with either fumes or dust. **Bellanger Bros. (London) Ltd., 306 Holloway Road, London, N.7.**

BCE 708 for further information

A New Micro Pump

The Distillers Co. have developed a micro pump for use primarily in laboratories where a small constant flow is

required. However, the pump may be varied in capacity infinitely and it has been used industrially for supplying small quantities of catalysts when a constant pre-set flow is required. Variation of flow is obtained by altering the stroke of the pump plunger. The pumps are made in a range of capacities varying from 0 to 7 cc per hour to 0 to 1500 cc per hour, and although they are intended to operate at low "discharge" pressures, they have, in fact, operated satisfactorily at pressures up to 100 psig. **The Distillers Co. Ltd., Engineering Division, Great Burgh, Epsom, Surrey.**

BCE 709 for further information

New Potential Rectifier

British Oxygen announce the introduction of a new constant potential 400-amp. rectifier (C.P.R. 400) for Argonaut welding. The rectifier provides automatic adjustment of arc conditions and reduces the possibility of burn-back, and the flat volt-ampere characteristic of the instrument allows the control of the wire-feed to be simplified by the elimination of voltage-sensitive relays. **The British Oxygen Co. Ltd., Bridgewater House, Cleveland Road, London, S.W.1.**

BCE 710 for further information

Other Items of Interest

A cold mastic jointing material suitable for ceramic and asbestos-fibre pipes is available from Key Engineering. A pitch-based compound, it is applied with a trowel, and, the makers say, it retains its flexibility yet does not flow. It is claimed that it is resistant to all normal effluents and, when buried, to the action of sulphate-reducing bacteria. **The Key Engineering Co. Ltd., 4 Newgate Street, London, E.C.1.**

BCE 711 for further information

A sifter and screen for dried powders incorporating a nylon, spiral revolving brush and a screen of mesh 250 or finer, held on stainless-steel bearers, is being made by **Longwood Engineering Co. Ltd., Parkwood Mills, Huddersfield, Yorkshire.**

BCE 712 for further information

Uses claimed for the Steelmaster straddle carrier include the conveyance of pipes in oil refineries. The vehicle, which straddles its load, can pick up a consignment of piping or girders 50-60 ft long in five seconds and carry them over rough ground at 25 miles per hour. **British Straddle Carrier Co. Ltd., 7 Chesterfield Gardens, Curzon Street, London, W.1.**

BCE 713 for further information

Shortly to be made available is a range of lightweight fibre tubes for structural engineering, of which the Sonoairduct type is intended for use in supply-and-return ducting of air-heating systems. It is lined with aluminium foil to reduce air-friction losses, is covered with black water-resistant asphalt kraft, will withstand temperatures up to 350°F, and can be laid in concrete. **T.P.T. Construction Products, The Textile Paper Tube Co. Ltd., Romiley, Cheshire.**

BCE 714 for further information

Recent improvements in design of Aerox air and gas filters have enabled the upper pressure limit of the appliances to be increased by 40%, to 7000 psi. The filters are fitted with ceramic elements manufactured by the company in four sizes of porosity, from 200 to 10 microns. **Aerox Ltd., Lister Place, Hillington, Glasgow, S.W.2.**

BCE 715 for further information

Alkalite polythene-tube fittings have been designed to make possible an all-polythene plumbing system without any special tube manipulation. During manufacture, two metallic rings forming a small heating element are moulded into each socket of the fittings. Two leads from the element project from the end of each fitting to form electrical connectors. Current supplied through the connectors from a heavy-duty battery heats locally both the fitting and the tube around the heating element, and welds the tube and fitting into one piece. **Imperial Chemical Industries Ltd., Kynoch Works, P.O. Box 216, Birmingham.**

BCE 716 for further information

Standard models of Pfister Waagen Weighbatching equipment, which are designed primarily for the building industry, weigh to an accuracy of 1%. The makers are prepared to alter the standard of the machines, however, to provide a more accurate performance (at least as accurate as ±0.6%) for use in the chemical industry. **Concrete Equipment & Metal Products (Westminster) Ltd., Orchard House, 14 Great Smith Street, Westminster, London, S.W.1.**

BCE 717 for further information

New Publications

"Carbon Tetrachloride" is the title of an eight-page booklet dealing with that solvent recently issued by Albright & Wilson Ltd., 49 Park Lane, London, W.1. The booklet deals with the principal applications of the compound, its medicinal uses, precautions to be taken in handling and considerations to be taken in the construction of plant in which carbon tetrachloride is used.

BCE 718 for further information

Midland Silicones Ltd., have issued a data sheet on experimental siliconate D3033, a new siliconate for making building materials water-repellent. The publication is available on request from the head office of the company, 19 Upper Brook Street, London, W.1.

BCE 719 for further information

The title "Training the Graudate for Production Management" has been given by Thomas Hedley & Co. Ltd., Newcastle upon Tyne, to a twenty-page book which describes briefly the method of staff training which they have evolved during twenty-six years' experience. The method is based on "training through responsibility".

BCE 720 for further information

Robert Dempster & Son Ltd. have issued a four-page illustrated leaflet describing their new sulphuric-phosphoric acid pickling plant for mild-steel plate and sectional material recently installed at Elland, Yorks.

BCE 721 for further information

Heath, Hicks & Perken (Thermometers) Ltd., New Eltham, London, S.E.9, have issued a new catalogue of mercurial and spirit-filled tube thermometers, hydrometers, hygrometers, etc. It is in binder form, is of seventy-one pages, and is abundantly illustrated. Notes are included on how to order the instruments.

BCE 722 for further information

To assist fuel-oil users during the present period of oil shortage, the Federation of British Industries, in co-operation with the National Industrial Fuel Efficiency Service, has compiled a leaflet entitled "Hints on Saving Fuel Oil". It lists twenty-five economy hints dealing with steam raising and utilisation furnaces, space heating, etc. Copies are available from the F.B.I. Headquarters, 21 Tothill Street, London, S.W.1.

BCE 723 for further information

A twenty-page illustrated brochure, 10¼ in. × 8¼ in., recently issued by Visco Engineering Co. Ltd., Stafford Road, Croydon, describes the company's range of self-cleaning air filters that are designed for handling large volumes of air for long periods. The text is amplified with tables of capacities and dimensions of the filters.

BCE 724 for further information

Evans Electroselenium Ltd., Harlow, Essex, have issued a four-page leaflet on the Eel portable colorimeter. It describes the instrument's construction, field of employment, calibration and methods of use.

BCE 725 for further information

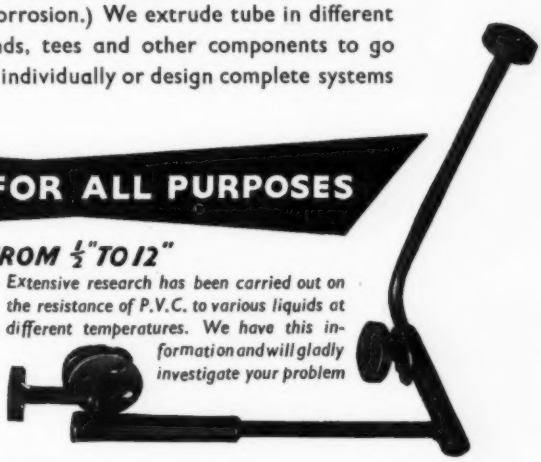
Have you a problem of CORROSION *or* CLEANLINESS?

We extrude and fabricate in unplasticised P.V.C. because it is the best and latest corrosion resisting material. (Plasticisers reduce resistance to corrosion.) We extrude tube in different gauges and make bends, tees and other components to go with it. We sell these individually or design complete systems for our customers.

PIPELINES FOR ALL PURPOSES

FROM ½" TO 12"

Extensive research has been carried out on the resistance of P.V.C. to various liquids at different temperatures. We have this information and will gladly investigate your problem



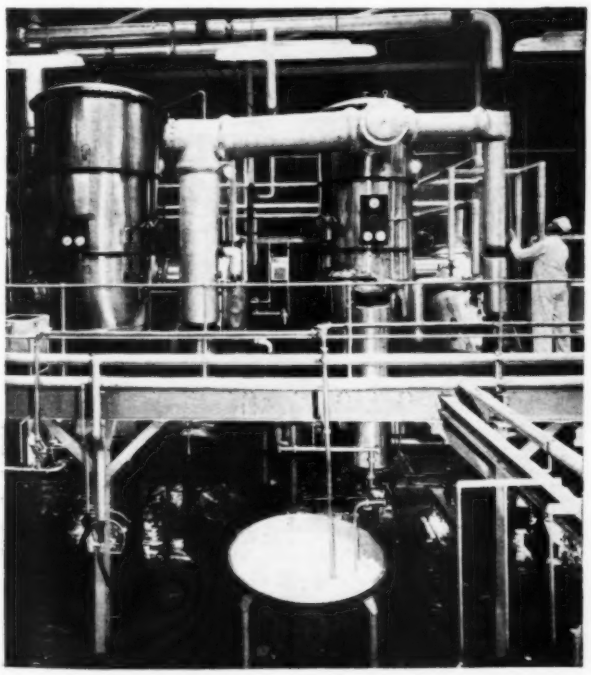
Send your enquiries to:—

EXTRUDEX LTD.

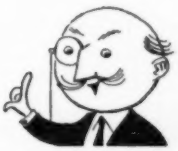
Rainbow 1170 WESTERN ROAD · BRACKNELL · BERKS. *Telephone: Bracknell 1000*

BENNETTS

Stainless Steel Double-effect Evaporating Plant for whey, installed at Express Dairy Company, Whittington, Shropshire.



Designers, manufacturers and suppliers of:



Evaporators (single or multiple effect) for the production of evaporated or condensed milk, dried milk powder, whey powder or paste, coffee, vegetable and fruit extracts etc., and all trade liquors. Also malt extract plant, food yeast plant etc.

Distillation Plant—continuous or intermittent—for producing alcohol (by glycerine or benzine process), rectified spirit, whisky, ether etc. and for acetone recovery. Also Bennett's patent Double-effect Distillation Columns. Complete installations or simple components.

Sea Water Distillation Plant of any size, for land or marine installation. Designs submitted for marine coil type, submerged calandria type or vapour compression type of evaporator.

Equipment supplied in Stainless Steel, Clad Material, Copper, Aluminium, 'Monel' Metal, Mild Steel etc.

BENNETT, SONS & SHEARS, LTD., 9-13 GEORGE STREET, MANCHESTER SQUARE, LONDON, W.1. PHONE: WELBECK 8201 (6 LINES) WORKS: BIRMINGHAM, LEEDS, LONDON.

World of Chemicals

New Zealand Fertiliser Factory

A contract amounting to just over £1 million has recently been placed with W. J. Fraser & Co. Ltd. for a complete factory to produce 100,000 tons of superphosphate a year. This contract is in addition to a similar one in the North Island. Senior staff from England will supervise construction and it is hoped to complete it in just under two years. The work will be carried out ,with the collaboration of Frasers' New Zealand agents, Cory-Wright & Salmon Ltd., and Downer & Co., of Wellington, whom Frasers have appointed as civil engineering contractors for the work. The factory will incorporate a sulphuric acid plant and the raw materials will be imported sulphur and Nauru phosphate rock. The factory will be built on a virgin site and involves administration buildings, rail sidings, packing and dispatch facilities.

Durban Chemical Factory

United Chemicals & Industrials Ltd. are operating a new factory at Durban. It is designed to facilitate the various manufacturing processes involved in the production of detergents and other chemicals.

Greek Nitrate Factory

The Greek Government has announced an international call for tenders for the construction of a factory to produce nitrate fertilisers, considered to be one of the greatest and most promising enterprises to be undertaken in recent years. The capacity of the new plant is to be 74,000 tons of nitrogen annually and the factory will use lignite from Ptolemais.

Istanbul's Chemical Allocations

It is reported that the Istanbul Chamber of Commerce has been allocated $10,000 for the importation of chemical products, and that the Ministry of Economy and Commerce has granted import licences to the value of $10,000 for pharmaceuticals, payment to be effected at the end of 1957.

Indian Chemical Commission

An Indian fact-finding commission of ten Government officials and advisers spent three days in Basle visiting local chemical and pharmaceutical firms. The commission had previously visited factories in Russia, East Germany and Italy.

Cuban Distributor Sued

Chas. Pfizer & Co. Inc. has asked the Havana Civil Court to issue an injunction to prohibit the unlicensed sale and distribution of tetracycline by Ganfersa, S.A., drug distributor in Cuba for Lepetit, S.p.A., Milan, Italy, which, Pfizer claims, has been manufacturing the antibiotic. Legal proceedings, filed in Havana on October 19, charge infringement of Cuban Product Patent 15,168, issued to Pfizer. Tetracycline is a broad-spectrum antibiotic discovered by Pfizer and marketed by the firm under the trade name "Tetracyn".

Resin Business Sold

The General Electric Co. of America has announced the signing of a contract for the sale of a portion of its interests in the manufacture of alkyd resins to Archer-Daniels-Midland Co. of Minneapolis, Minnesota. According to S. L. Brous, general manager of General Electric's chemical materials department, included in the transaction are finished goods inventories, equipment, formulations and manufacturing specifications related to the company's former production of Glyptal (R) alkyd resins. Mr. Brous said General Electric's decision to sell was based on the cost and time factors involved in reconstituting resin-making facilities equivalent to those formerly in production at the company's Schenectady plant. These facilities were destroyed by an explosion and fire on March 21 last.

Du Pont's New Department

The Du Pont Co. has announced the creation of a new department, Elastomer Chemicals, to be responsible for research, production and sales for all products currently handled by the Elastomers Division of the company's organic chemicals department. The new department brings the total of the company's operating departments to eleven. The new department becomes effective from January 1, 1957.

Dunlop's Chemical Awards

Three members of Dunlop's chemical research department and one of their polymer development section are among eight employees who have each been awarded £25 under the company's part-time education scheme upon receiving the B.Sc. degree. Twenty-three other employees who have gained national and other certificates in chemistry share total awards amounting to £1190.

Production of Succinamide

The American Cyanamid Co. has evolved a new process for the production of succinamide, a chemical which can be used in processing starch or cellulose.

New Canadian Plant

A new manufacturing plant has been opened in Arnprior, Ontario, by the international drug and chemical firm of Pfizer. In its first phase of operation, the plant will package such drugs as Terramycin and the new synergistic antibiotic combination, Sygmamycin. The new plant is one of seventeen Pfizer plants outside the U.S. completed or now under construction. Other plants were opened last year in Chile, Argentina and Japan, and some are scheduled to be opened this year in Italy and Turkey.

Research In Germany

The annual report of Chemische Werke Hüls A.G., Germany, refers to the outstanding success during 1956 of the production of low temperature rubber Buna-Hülls K. Production processes for Buna OP rubber were improved, and the manufacture of a number of polymers, such as suspension polyvinyl chloride, polyester resins and polyethylene, was started.

Pakistan Starch Industry

On the recommendation of its Tariff Commission, the Government of Pakistan has decided to protect the country's starch industry until September, 1958. An import duty of 36% *ad valorem* has been imposed on sago flour and the existing revenue duty of 18% *ad valorem* on imported maize starch will be converted into a protective duty. Other assistance, more directly connected with increasing production, also is to be given.

Lysine By Fermentation

The first commercial fermentation of lysine has been announced by Chas. Pfizer & Co. Inc. The development, a notable advance in biochemical engineering, was made possible, the company says, by the use of fermentation techniques developed in the manufacture by fermentation of vitamins, antibiotics, hormones and other complex chemicals. The product, L-lysine, contains no D-lysine and is a pure crystalline powder with a purity of not less than 98%.

New Use for Antibiotics

Eight new antibiotics were described at the Fourth Annual Symposium on Antibiotics held in Washington recently under the sponsorship of the Division of Antibiotics of the American Food and Drug Administration and two antibiotic journals. Practically an entire day was allocated to a discussion of the use of antibiotics as food preservatives, and proposals put forward in this section included the possible use of broad-spectrum antibiotics in conjunction with radiation.

Canadian Sulphuric Acid Plant

Canadian Industries, in which Imperial Chemical Industries of Canada is a large shareholder, plans to spend at least $3 million to construct a new sulphuric acid plant at Copper Cliff, near Sudbury (Ontario). The plant will be similar to that used at the adjoining International Nickel's Copper Cliff smelter and will use sulphur-containing waste gases from iron production. Its output will be 300 tons of acid a day, and the product will be used in extracting uranium concentrates.

Coating of Titanium

The American National Bureau of Standards has successfully deposited hard, adherent protective coatings on titanium by electrical methods. The procedure involves forming a titanium fluoride film on the metal surface, electroplating with chromium, and heat-treating the plated specimen at 800°C. Developed for the Springfield Armory by C. L. Stanley and A. Brenner of the Bureau staff, the process is expected to extend considerably the utility of titanium metal, particularly for high-temperature application.

HOW CAN A PREMIER MILL HELP YOU?

BY GIVING HIGHER YIELDS

BY SPEEDING UP REACTIONS

BY SAVING CATALYSTS

BY ENSURING CONSISTENT QUALITY

DISCUSS YOUR PROBLEMS WITH **PREMIER COLLOID MILLS LIMITED**

IF YOU ARE CONCERNED with the manufacture of products where intimate contact conditions are essential, then Premier Colloid Mills are essential in your plant.

In the Chemical Industry Premier Colloid Mills have not only proved their value by the advantages listed above but they have also shown important savings in manufacturing costs.

In the development of their wide range of mills Premier technicians have gained, the practical way, a very great deal of experience. This experience is at your service.

The NEW 3" MULTIPURPOSE COLLOID MILL illustrated is the most versatile mill yet produced in Britain. You will find it invaluable, not only for small production work, but also for carrying out tests under conditions identical to factory production.

HERSHAM TRADING ESTATE · WALTON-ON-THAMES · SURREY · TEL.: WALTON 6305

The Month's News in Brief

The 130-ft diameter sphere which will contain the Dounreay fast reactor is rapidly approaching completion at Caithness, Scotland. About 1400 tons of steel have been used in its construction. The Dounreay scheme is due to become operational in 1958 (Photo: Scotsman).

Anglo Great Lakes Corporation, a new British company, has been formed to manufacture special-quality graphite required for nuclear reactor furnaces. The new company, the second such company to enter this specialised field, is to spend £6 million on the construction of a production plant at Newburn Hengl on the banks of the River Tyne. Previously the total production of nuclear graphite in the U.K. has been manufactured by British Acheson Electrodes. The group of companies supporting the new venture are: C. A. Parsons & Co., A. Reyrolle & Co., Sir Robert McAlpine & Sons., and Clarke Chapman & Co. in collaboration with the Great Lakes Carbon Corporation of America. The new plant is due for completion in December, 1958.

Brush Electrical Engineering Co. Ltd. has obtained through Kellogg International an order for six gas expansion turbines to be installed in a new chemical plant by I.C.I., Billingham Division. These turbines will range in output from 3000 h.p. downwards and will be used for driving centrifugal compressors.

Shell are to install two electronic computers at their Stanlow Refinery, and another one at Shell Haven.

DuPont Co. (U.K.), a subsidiary of E. I. duPont de Nemours, U.S.A., has taken options on a 381-acre tract near Londonderry, Northern Ireland. The site is for a neoprene synthetic rubber plant. Plant construction is expected to begin in early 1957.

Mono Pumps Ltd. has formed a company to be known as Mono Pumps (Africa) (Pty.) Ltd. to foster interest throughout the continent of Africa. The directors of this new company are chairman: H. B. Hichens; managing director: A. Taylor; directors: A. W. Gregory, R. R. Kennan (Alternate A. R. McCall). The new company has purchased a modern factory and offices in the Johannesburg district and will follow independent lines of development suited to the circumstances and peculiarities of the area covered.

Head Wrightson Processes Ltd. have announced that the butadiene extraction plant engineered by them for I.C.I. at its Wilton Works has been completed and successfully operated at the design rate of several thousand tons per annum.

Babcock & Wilcox have received an order for the construction of the reactor vessel for Canada's first nuclear power plant. This is for the N.P.D. (Nuclear Power Demonstration) project, which will also be the first nuclear power plant in the Commonwealth outside Great Britain. The Canadian General Electric Co. are the main contractors.

Isotope Developments Ltd. is acting as consultants to Landis & Gyr A.G. for the instrumentation of the new high-power Swiss 20-megawatt materials testing heavy-water-moderated reactor which is being designed and built by Reaktor A.G. Isotope Developments are responsible for the recommendation and supply of the full nucleonic instrumentation, which includes the equipment for the channels for controlling and safeguarding the reactor and its surroundings.

The Northampton Polytechnic have announced a course of ten lectures on atmospheric pollution and current problems in the more efficient use of fuels. The lectures will be delivered by a number of specialists in the various fields on Monday evenings at 7 p.m., commencing on January 28, 1957. Fee for the course is 20s. and enrolment may be effected by personal attendance at the Polytechnic or by post, in which case those wishing to enrol should supply the following information: (a) name and address; (b) qualifications; (c) name of employer (required for record purposes only) and enclose the fee and a stamped addressed envelope to J. Leicester, The Northampton Polytechnic, St. John Street, London, E.C.1.

A design study and development work to determine the feasibility and economics of heavy-water-moderated reactors for electric power generation will be undertaken for the Atomic Energy Commission by E. I. duPont de Nemours & Co. The study will pay particular attention to the utilisation of natural uranium as fuel.

A further stage in the expansion programme of British Oxygen Gases Ltd. was reached when the Duke of Devonshire recently officially opened the company's new factory at Brinsworth, near Rotherham. During the opening ceremony, the Duke set in motion a liquid-oxygen-producing plant, which is one of six new large plants which B.O.G. are installing in various parts of the country to meet the increased demands for gases from industry. This new plant is part of a large industrial project at Brinsworth which will ultimately cost £2 million. Within two years, B.O.G. plans to build an oxygen-compressing station, a dissolved acetylene factory, a loading dock, a garage to accommodate 60 commercial vehicles, and a works demonstration and service block. B.O.G. may also erect a unit for the production of nitrous oxide at a later date.

A six-week course to enable members of industrial companies to acquire the basic knowledge of nuclear engineering has been arranged by the U.K.A.E.A. and is to be held at Harwell from June 3 to July 12, 1957. Some 60 places will be available and application forms for places may be had on request from the Reactor School, A.E.R.E., Harwell, Berkshire. Selections for places will be made in early March, 1957.

Investigation by the Central Electricity Authority has shown that a site at Inkley Point, Somerset, has qualities that make it admirable for a nuclear power station and, having reviewed the forward programme for both coal and nuclear stations, the Authority has concluded that it should be developed for its third nuclear power station. Construction of the first two stations in the Government programme at Bradwell, in Essex, and Berkeley, in Gloucestershire, will start in 1957. Tenders in respect of these stations from four groups of manufacturers are now being examined by the Authority.

Acknowledgment is due to *The Rubber & Plastics Age* for permission to reproduce the photograph illustrating the extrusion of nylon pipe which appeared on p. 370 of the November issue of *British Chemical Engineering.*

BCE 651 for further information

CHROMATOGRAPHY & ELECTROPHORESIS

For One and Two-way Paper Separation

'CENTRAL' AUTOMATIC FRACTION COLLECTOR

For Column Chromatography. Designed to eliminate drainage errors.

Collector plate available in 4 sizes.

Collections from 2 c.c. to 50 c.c.

ALSO GLASS SPRAYS, COLUMNS, FILTER PAPERS, ETC.

AIMER

PRODUCTS LIMITED

56/58 ROCHESTER PLACE, CAMDEN ROAD, N.W.1

DENSO IN ACTION

Recent DENSO advertisements have approached a frightening fact in light-hearted vein. Now, in serious mood, see DENSO actually being wrapped round pipes—a very important business. Those who decide specifications appreciate the value of 30 years' experience and choose DENSO.

Five 8" diameter aviation refuelling mains at Shannon Airport. Primed with Denso Paste and wrapped with Denso Tape, welded joints are now being protected.

DENSO REGD. ANTI-CORROSION PRODUCTS

Trade Mark

Write for full details to:

WINN & COALES LTD.

DENSO HOUSE, CHAPEL ROAD, LONDON, S.E.27

Telephone: GIPsy Hill 4247 (4 lines). *Telegrams: Denselte, Westnor, London*

BCE 652 for further information

People In The News

MR. GEORGE BREARLEY, *new director of the A.B.C.M. (see "Digest").*

At the anniversary meeting held in late November, **Sir Cyril Hinshelwood** was re-elected president of the Royal Society. **Sir William Penney,** K.B.E., director of the Atomic Weapons Research Establishment, Aldermaston, was elected treasurer in succession to **Sir Thomas Merton,** K.B.E., to whom the president paid warm tribute for his wise guidance of the Society's financial affairs during his term of office since he was first elected in 1939. The other officers re-elected for the ensuing year were: physical secretary, **Sir David Brunt,** who is chairman of the Electricity Supply Research Council of the Central Electricity Authority; biological secretary, **Professor G. L. Brown,** C.B.E., Jodrell professor of physiology at University College London; and foreign secretary, **Dr. H. G. Thornton,** head of the department of soil microbiology at Rothamsted Experimental Station.

Among other members of Council elected were: **Sir Claude Gibb,** K.B.E., chairman and managing director of C. A. Parsons & Co. Ltd., and **Dr. B. F. J. Schonland,** C.B.E., deputy director, Atomic Energy Research Establishment.

Mr. E. P. Hudson, assistant managing director and technical director of Scottish Agricultural Industries Ltd., Edinburgh, has been appointed chairman of the Edinburgh and South-east Scotland Regional Advisory Council for Technical Education.

Amber Pharmaceuticals Ltd. announce the appointment of **Mr. Francis de Buda** to the board of the company. Mr. de Buda will be concerned with the development and marketing of the products of Amber Industrial Chemical Treatments (a division of the company). These consist of a number of products relating to boiler feed-water treatment and industrial fuel utilisation. They have been developed, in large part, as the result of new continental research into these problems.

Sir Alexander Fleck, chairman of I.C.I., has received the honorary degree of Doctor of Science of the University of Oxford.

As a result of the death of **Mr. H. Shoosmith,** late chairman of Plenty & Son Ltd., **Mr. G. T. Shoosmith** has been appointed chairman and managing director, and **Mr. M. A. H. Walford** as deputy managing director.

Among the awards of medals made by the President and the Council of the Royal Society are: The *Rumford Medal* to Dr. F. P. Bowden, Reader in Physical Chemistry in the University of Cambridge, for his distinguished work on the nature of friction; The *Davy Medal* to Professor R. D. Haworth, Firth Professor of Chemistry and Head of the Chemistry Department in the University of Sheffield, for his distinguished contributions to the chemistry of natural products, particularly those containing heterocyclic systems; and The *Hughes Medal* to the Right Honourable Viscount Cherwell, lately Professor of Experimental Philosophy in the University of Oxford, for his distinguished work in many fields: the melting-point formula and theory of specific heats; ionisation of stars; meteors and temperature inversion in the stratosphere.

A. G. Stewart

C. W. Elliott.

The President of the Board of Trade has announced the appointment of **Mr. A. G. Stewart,** chairman and general managing director of Stewarts & Lloyds Ltd., to be a part-time member of the Iron and Steel Board. He replaces **Sir Andrew McCance,** F.R.S., who at the end of his period of office on May 31, 1956, did not seek re-appointment.

Remington Rand have announced the formation of an electronics division. Heading the new division is **Mr. C. W. Elliott** as its national sales manager. Mr. Elliott held a staff appointment with the scientific adviser to the Army Council. He then became deputy assistant director, Scientific Research, at the War Office and was responsible for method research studies and man-power utilisation research. Appointed to the General Staff, War Office, as organisation and methods officer, he was responsible for the mechanisation of accounting processes in large Army store depots and for the introduction of machines to effect man-power economies. He left the Army with the rank of Major and joined Remington Rand in 1952.

The appointment of **Mr. Geoffrey Sims-Davies** as equipment manager of British Oxygen Gases Ltd. has been announced. He joined British Oxygen in 1938.

PROF. P. V. DANCKWERTS, *Newly appointed Professor of Chemical Engineering Science, Imperial College of Science and Technology (see "Digest").*

Mr. James B. Longmuir, who has represented Megator Pumps & Compressors Ltd. in Scotland for the past six years, has been appointed to the newly created post of Scottish regional manager. His son, **Mr. James B. Longmuir,** has been appointed as an additional Scottish technical representative.

The Central Electricity Authority has appointed **Mr. D. G. Dodds** chief industrial relations officer with effect from January 1, 1957. In this capacity, Mr. Dodds will be responsible for a range of functions which will include the negotiating machinery, covering wages and conditions of employment throughout the electricity supply industry, the fields of education, training, safety, health and welfare and the joint consultation machinery.

The National Coal Board has appointed **Mr. W. H. Sales** to be chairman of the North-eastern Division in succession to **Major-General Sir Noel Holmes** who is to vacate this office on January 31, 1957. The Minister of Fuel and Power has, at the request of the National Coal Board, agreed to the termination of Mr. Sales's appointment as a member of the National Coal Board at the same date, to enable him to take up his new post.

Mr. E. G. Thompson has been appointed technical sales manager of Baird & Tatlock (London) Ltd. He has relinquished his post of public relations officer, and this function has now been taken over by **Mr. D. J. Wykes.**

Obituary

Awarded the Colwyn Medal for conspicuous services to the rubber industry, **Mr. S. A. Brazier** died suddenly on the night of Sunday, November 25. Born in Birmingham 66 years ago, Mr. Brazier joined Dunlop's technical staff after demobilisation from the 1914 war as deputy to their chief chemist, the late **Dr. T. F. Twiss,** and head of the chemistry research department. Mr. Brazier has played a prominent part in the British Standards Institution's work of standardisation and was chairman of the Rubber Industry Standards Committee. He was also chairman of the committee which creates internationally acceptable methods to test rubber products for which the British Standards Institution is the organising secretariat. He was a member of the Chemical Divisional Council; chairman of the International Organisation Committee for Rubber; and for nearly 30 years he had been chairman of the technical committee of the rubber manufacturers' trade organisations. In the latter capacity, Mr. Brazier became chairman of the industry committee advising rubber control during the Second World War on the problems connected with the shortage of natural rubber and the conversion of industrial goods to synthetic rubber. For this service he received the O.B.E. in 1948. He was also a fellow of the Rubber Industry's Council and of the Institution of the Rubber Industry, of whose Council he was chairman.